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Methods For Restoring Shape And Structure Of Compressed Dehydrated Animal And Combination Products

Foster D. Snell, Incorporated

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The investigation was designed to study the feasibility of using plasticizing agents or other pretreatments to aid in the reversible compression of animal and combination food products.

Results suggest that propylene glycol and glycerol were the two plasticizing agents of choice even though they generally required the addition of a small

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quantity of steam as a synergist, probably to allow better penetration of the plasticizers to compact the tissues without fragmentation during compression.

During the investigation several new, apparently technically viable approaches were developed. including a split stream process and a process we called "continuous compression freeze-drying". Neither concept was thoroughly investigated because of time and budget constraints.

The reversibly compressed animal and combination food products were stored under nitrogen in sealed pouches for 90 days at -18C, 28C, and 38C. Aliquots were removed every 30 days and subjected to objective and sensory evaluation. The storage studies of the compressed foods indicated a tendency to progressive deterioration in flavor and color, as well as texture, particularly when stored at 38C.

The different foods investigated had distinctly different storage characteristics. The products containing chicken seemed to deteriorate most. Compressed shrimp, chili con carne, and diced beef did not deteriorate more than uncompressed, freeze dried controls. Meatballs showed slight deterioration while the other foods scored between the extremely affected products.

SUMMARY AND CONCLUSIONS

The major objective of the investigation was to demonstrate the feasibility of one or more commercially viable procedures for the reversible compression of animal and combination food products. Several concepts were investigated, including the following:

- the use of disappearing plasticizers such as FDA approved Freons and liquefied gases.
- continuous compression freeze drying.
- split stream treatment.
- the use of vaporized propylene glycol.
- vacuum distillation in the presence of propylene glycol.

The use of propylene glycol or glycerol as plasticizing agents in combination with a brief steam treatment immediately before compression yielded compressed foods of the best quality. Continuous compression freeze drying, although not thoroughly studied, appeared to be a technically viable approach with commercial potential and further work seems warranted on this concept to evaluate its parameters.

The compressed products were stored for 90 days at -18C, 28C, and 38C. The products had a tendency to deteriorate during this time period, particularly at 38C as evidenced by discoloration, the appearance of off-flavors, and the inception of an undesirable aftertaste. Not all foods deteriorated to the same degree. Those containing chicken had the least shelf life. Compressed shrimp, chili con carne, and diced beef, on the other hand, did not deteriorate more than untreated freeze dried controls.

From the investigation, it was concluded that the propylene glycol or glycerol combination with steam, when used under optimum conditions, were not the major cause of deterioration. It appeared that some of the food components, such as unsaturated lipids, sugars, protein fractions, and myoglobin in meats brought about deterioration, particularly in the presence of oxygen and light. While it is suspected that undesirable Maillard reactions were taking place, other chemical reactions of an unknown nature may have been involved. These factors need to be investigated because means to prevent or minimize deterioration can be developed only after the nature of the chemical reactions involved has been elucidated.

FOREWORD

The reversible compression of dehydrated foods into modular bars combines near-maximum weight reduction with a heretofore unattainable volume economy and packing efficiency. These advantages can be realized with many common foods without appreciable sacrifice of normal sensory characteristics and other essential qualities when the food is consumed after hydration. Current technology for achieving reversible compression requires a plasticizing operation in which dry food is equilibrated to 8-12 percent moisture prior to compression. When prolonged storage is a requirement, the moisture content of the compressed product must be reduced to near 2 percent. The commercial attractiveness of reversible compression, and hence the availability for military applications, is seriously impaired by the additional dehydration requirement and the pre-compression equilibration to a prescribed moisture level. The objective of this investigation is to develop and demonstrate procedures to advance the commercial feasibility of reversibly compressed foods. The need for this technology is supported by a recommendation from the National Research Council Committee on Animal Products.

The experimental program herein described was performed by Foster D. Snell, Inc., Florham Park, New Jersey with funds provided under Project No. 1T762713A034, titled: Military Food Service and Subsistence Technology. Dr. Abraham Bakal served as Principal Investigator throughout most of the contract under the general direction of Dr. Kurt S. Konigsbacher, Vice President, Foster D. Snell, Inc. During final phase of this contract, Dr. Bakal was granted leave to pursue a project in South America whereupon Dr. Konigsbacher assumed the duties of the Principal Investigator. Dr. Maxwell C. Brockmann and Dr. Larry C. Hinnergardt served as Project Officer and Alternate Project Officer, respectively, for the U.S. Army Natick Development Center.

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INTRODUCTION

The project entitled "Methods for Restoring Shape and Structure of Compressed Dehydrated Animal and Combination Products" was carried out under the U. S. Army Natick Contract No. DAAG 17-73-C-0030. The major objective of the study was to demonstrate the feasibility of one or more commercially viable procedures for the reversible compression of animal and combination products in which the plasticizing agents used to prevent fragmentation by compression need not be removed from the compressed mass after compression.

One such technique consists of freeze-drying foods to a final moisture content of 2 to 3 percent, followed by reconditioning with water to a moisture level of between 7 and 10 percent, compression and freeze drying to a final moisture content of 2 to 3 percent. It is obvious that this procedure is costly since it involves the addition of water before compression, and its subsequent removal after compression. Thus, the U. S. Army Natick Laboratories authorized this study in order to identify:

- alternate procedures for compression
- alternate acceptable plasticizing agents to be used instead of water, which do not require special steps for their removal
- a combination of the above.

The following products were investigated:

a) Cooked, diced beef free of trimmable fat and connective tissue

b) Cooked, diced white meat of chicken or turkey, free of skin and trimmable connective tissue

c) Blanched, diced carrots

d) Cooked Shrimp

e) Beef stew (formulation equivalent to beef stew of Food Packet, Long Range Patrol)

f) Chili and beans (formulation equivalent to chili and beans of Food Packet, Long Range Patrol)

g) Chicken and rice (formulation equivalent to chicken and rice of Food Packet, Long Range Patrol)

h) Cooked meat balls.

ANALYSIS OF OPTIONS AVAILABLE AND THE EVALUATION OF INNOVATIVE IDEAS

The plasticizing agents and techniques used for the reversible compression of animal and combination products were investigated using classical and innovative approaches.

A. Classical Approaches

Classical approaches were based on the replacement and/or binding of the water by other plasticizing agents which will not have to be removed from the food item.

The materials suggested and tried for this purpose include:

- gelatin
- propylene glycol
- glycerol
- fat
- oil
- propylene glycol/water
- propylene glycol/gelatin
- gums (CMC, carrageenan, etc.)
- starch
- CMC/lactose
- gluten and/or egg albumin

The details on the application of the above materials and techniques used may be found in Section V on the investigation of plasticizing agents and techniques.

B. Innovative Approaches

As an integral part of this investigation, a number of ideas were evaluated. In some cases, the conclusions drawn are based on very limited experimental results. However, they will be presented in this section with a view towards further experimentation.

1. Vanishing Plasticizers

The possibility of utilizing plasticizers which have a boiling point at or below ambient temperature was explored. Possible materials which were identified, included:

- FDA approved freons

- Liquefied gases such as carbon dioxide

In a series of preliminary experiments, diced carrots and diced chicken were immersed in freon and immediately compressed. The resulting compressed mass was totally fragmented. This may have been due to the following reason:

- Although freon does act as a plasticizer for food items, the rapid decrease in the temperature of the food due to the evaporation of the freon during compression caused hardening of the cellular structure. Measurements of the temperature of the food during the compression cycle showed that the food was, indeed, frozen hard.

It was quickly realized that further investigation of this approach required the design of a special compression cell. Since, in the work authorization, money was not allocated for the design and manufacture of the cell, it was decided not to pursue this approach further at this time. Thus, it is impossible at this stage to evaluate the feasibility of the approach. Only after a cell has been manufactured, and the problem of temperature reduction has been solved, would it be possible to evaluate the viability of this concept.

The idea of utilizing a mixture of freon and oil as a means for the oil to penetrate into the product was also explored. The initial experiments in this direction were unsuccessful.

2. Continuous Freeze Drying and Compression

Pieces of cooked, frozen, diced chicken, containing no plasticizers, held in a clamp under constant load, were placed on the freeze-drier shelves and freeze dried. The magnitude of the load was not evaluated.

At the end of the drying cycle, the diced chicken had been compressed to about half its original size. When the pieces were rehydrated, they returned to their original shape with no obvious changes in texture and clearly resembled the reconstituted, freeze dried, uncompressed chicken in all aspects.

This finding opens a new approach to simultaneous freeze drying and compression. Further investigation of this approach was not carried out because of the need of new equipment design, which was not, per se, part of the terms of this contract. However, this approach represents a concept that needs to be investigated further because of its potential as a one-step process.

3. Split Stream Treatment

The classical approach to compression technology and using water as the plasticizing agent consists of drying a food product to the final moisture content, add water to bring the moisture up to 7 to 10 percent, and re-drying the food product to the final moisture level. Thus, the total amount of water that has to be removed during the process is about 10 percent higher than the original moisture content. Obviously, this treatment is inefficient and costly.

Using a split stream process should be significantly more efficient. The concept can be described as dividing the original food product into two parts. One part is freeze dried to the final moisture content. The other part is not dried. Instead, it is allowed to equilibrate with the dry food so that the water from the wet part acts as the plasticizer for the dry product. Thus, no additional water is applied and using the food as the source of water cuts down the total quantity of product to be dried.

As a theoretical example, the following was calculated:

- Classical Approach: To produce 89N of compressed, dehydrated food with an original moisture content of 80 percent, requires the removal of 356N of water in the first drying cycle, the addition of 8.9N of water for plasticizing before compression, and the removal of the 8.9N of water in the second drying cycle. The total water to be removed is 365N and the total drier loads 543N.

* <u>Split Stream Process:</u> To produce 89N of compressed, dehydrated food with an original moisture content of 80 percent, only 434N are put through the first drying cycle, removing 347N of water. The dry food (87N) is then equilibrated with the 11N of wet food. The mixture (98N) is then re-dried to remove 8.9N of water. Thus, the total water removed is 356N and the drier loads 532N.

Of course, the efficacy of this approach is believed to be much more significant than is apparent from the above calculations. Initial drying could be achieved by a method that is less costly than freeze-drying and the proportion of wet to dry food used for equilibration could be varied substantially by partially drying the wet portion before mixing.

To test the validity of the concepts, some preliminary experiments were conducted with diced carrots and diced chicken.

a) <u>Diced Carrots</u>

Diced carrots were blanched in steam for 7 minutes. They were split into two parts. One part was freeze-dried to a moisture content of 1.4 percent, the other part was stored wet (85 percent moisture) in the refrigerator.

It was calculated that it would be necessary to add 1.6 grams of wet carrots to 10 grams of freeze-dried carrots to bring the moisture content of the combined system to 12 percent. The following process variations were explored for vacuum storage:

* wet pieces were frozen, mixed with dry carrots and the combination was stored in the freezer.
* the combined system was stored at ambient temperatures.
* the combined system was stored at 38°C.

The samples stored at 38°C showed significant shrinkage of the wet pieces. The samples stored at ambient temperature behaved similarly, but there was less shrinkage. The frozen samples showed no shrinkage but there was no significant moisture transfer and the samples were removed to ambient temperature to facilitate moisture transfer.

All samples were examined after 24 hours storage for moisture content which ranged from 9.3 percent to 9.5 percent. It was noted that the diced carrots were plasticized and could be compressed. The following compression and rehydration data was obtained:

	Compress-ibility	Compression Ratio	Rehydration Time
Frozen/ Ambient Storage	easy	9.2	25 min.
Ambient Storage	easy	7.9	16 min.
38°C Storage	easy	8.7	12 min.

All samples had an excellent texture after rehydration and there was a discernible trend that higher storage temperatures tended to reduce rehydration time which points up the importance of heat relative to increasing the moisture transfer rate.

Although the wet pieces had a tendency to shrink, their proportion was small enough so as not to be noticeable and the product was judged to be acceptable. Since storage at elevated temperature appeared to favor moisture transfer and rehydration time, an additional series of experiments was carried out as follows:

> To ten grams of freeze dried carrots was added 1.7 grams of wet blanched carrots. The mixture was stored under vacuum at 38°C as shown in Table I (APPENDIX).

The data indicated:

- Equilibration for 4 hours at 38°C was sufficient to render the system compressible.
- Moisture transfer continues even after 24 hours storage.
- The moisture content necessary for plasticizing action fell into the 5.5 to 7.0 percent range.
- Rehydration time was improved only if the moisture level during the second freeze-drying cycle was low.
- There was no noticeable change in color.

b) Diced Chicken

A series of experiments was carried out to investigate the moisture transfer with diced cooked chicken. The experimental design was similar to that used for diced carrots.

The proportion was 10 grams of freeze dried chicken and 1.7 grams of wet, cooked chicken. Samples were removed after 2, 4, 6, 17, and 24 hours storage and evaluated for compressibility, color, and flavor changes, and rehydration characteristics. The results of the tests are summarized in Table II (APPENDIX). The data indicated [illegible]:

- At a moisture level of 6 percent, the product is reversibly compressible.
- Six hours equilibration was sufficient to transfer enough moisture for compression.
- The total shrinkage of the wet pieces did not exceed 50 percent.
- Rehydration time was less than 2 minutes.
- No color change was noticed even after 24 hours storage at 38°C.

Based on the experiments carried out, it was concluded that the split stream process represents a promising and viable approach, particularly if it can be modified to increase cost savings by means of an initial reduction in moisture content.

4. Propylene Glycol Vaporization

The temperature/vapor pressure relationship for both glycerol and propylene glycol is summarized in Figure 1 (APPENDIX). The drawing shows that propylene glycol is more volatile than glycerol and can be volatilized at room temperature under reduced pressure.

Since one of the major problems in plasticizing the foods under test is believed to be directly related to the penetration of the plasticizing material into the food product, it was hypothesized that the introduction of propylene glycol in gaseous form might eliminate the need to add water in the form of steam.

In an attempt to test this theory, freeze dried carrots were subjected to a high vacuum at 50°C. This operation was necessary to remove the air from the spaces formed in the diced pieces during freeze drying. One gram of propylene glycol was added for each 10 grams of carrots. Samples were removed after having been allowed to equilibrate for 2, 4, 6, 17, and 24 hours. After removal, the carrots were compressed. Results indicated that equilibration for 4 hours was sufficient to achieve tissue penetration by the plasticizer as evidenced by the compressibility of the product.

The same technology was also applied to cooked shrimp and cooked diced chicken. Results of experiments using the same ratio of propylene glycol and a four hour equilibration period were discouraging because the plasticizing material did not appear to penetrate the tissue as evidenced by the damage to the product during compression. While the reason for the failure of the experiments has not been ascertained, it may be attributed to one of the following factors:

- Both shrimp and chicken have a denser texture so that an equilibration time of 4 hours may not have been sufficient.

- The removal of air from the spaces in the diced pieces of shrimp and chicken may have been incomplete because of the dense texture. As such, the air left in the spaces may have acted as a barrier for the penetration of propylene glycol.

5. Vacuum Distillation in the Presence of Propylene Glycol

The behavior of the propylene glycol during the freeze drying cycle led to the concept of dehydration by removing the water through vacuum distillation of the water in a propylene glycol solution. This approach was based on the following theoretical considerations:

- Since propylene glycol could be removed from the system at relatively low temperatures when a high vacuum was applied. it may be possible to remove a water/propylene glycol mixture at low temperature but without having to freeze the food.

- As the water evaporates, propylene glycol may replace the water in the intercellular structure and, thus, decrease the extent of shrinkage normally encountered in vacuum dehydration.

- It should be possible to control the removal of propylene glycol so that enough propylene glycol is left to act as a plasticizer.

To test the approach under practical conditions, experiments were conducted with diced cooked chicken and cooked shrimp. In these experiments, 40 grams of the food product was mixed with 100 grams of propylene glycol in a distillation flask; the mixture was allowed to equilibrate for a short period of time and vacuum distilled in a "Roto Vac" evaporator with the bath temperature being kept at 30C. After evaporation, considerable shrinkage could be observed, albeit less than under normal drying conditions. Also, it was found that the drying time was much shorter and that the foods had become highly plasticized and pliable, and could be separated from excess propylene glycol. Color and texture both were judged to be good. However, when attempts were made to compress the foods without removal of excess propylene glycol, they suffered mechanical damage and rehydration times were very slow. The behavioral characteristics appeared to be the same as when an excess of water was used for plasticization before compression.

The data indicated the potential value of the technique which merits further investigation. However, its applicability to the current problem seems limited and we did not investigate this approach further. Rather, potential applications may be in the field of intermediate moisture foods where glycerol may be used as the heat transfer medium.

6. Application of Pressure to Improve Penetration of Plasticizers

Since it was theorized that improvement in the penetration of the plasticizing agent into the tissue would enhance product performance, the application of pressure was evaluated as a means to facilitate penetration.

Freeze dried, commercial, diced, cooked chicken was placed in pressure containers and sprayed with either a mixture of 75 percent propylene glycol and 25 percent water, a mixture of 75 percent glycerol and 25 percent water, or with propylene glycol only.

The solutions were applied at a level calculated as 15 percent of the dry product weight, the propylene glycol at a 10 percent level. The pressure containers were sealed and pressurized with nitrogen to 6.9×10^5 Pa. Corresponding controls were kept at atmospheric pressure.

While the results of the experiments with the solutions did not show any differences, compressibility of the pressurized sample treated with propylene glycol only, appeared to be slightly improved.

In view of the disappointing observations, that product performance was not really improved, this approach was not pursued further.

IV. MATERIALS AND METHODS

A. Materials

For the preliminary experiments, the raw materials used were selected to save preparation time. Thus, whenever possible, prepared materials were utilized. To obtain better control of the variables involved, freshly processed raw materials were applied in later experiments. The materials used for the initial studies designed to elucidate major problem areas are described briefly below. The preparation of the raw materials for the optimization experiments is given in the appropriate sections of the report.

1. Diced, Blanched Carrots

Tunnel dried, diced carrots were reconstituted with water, and used in all preliminary experiments. The carrots were purchased from Basic Vegetables.

2. Diced, Cooked Chicken

Three types of materials were investigated since it became obvious as the study progressed that the "history" of the material strongly influences its performance.

a. Diced, Cooked Frozen Chicken Roll: purchased from a food broker. This material contained soybean flour, salt and other additives.

b. Diced, Cooked Chicken: prepared from chicken breasts bought locally, cooked in boiling water and diced.

c. Fabricated, Cooked Diced Chicken: prepared from shredded chicken pieces, raw chicken emulsion, and other additives. The loaves were baked in an oven, cooled, and diced.

3. Diced, Cooked Beef

Sirloin beef was sliced, cooked in boiling water and diced.

4. Diced, Cooked Turkey

Turkey roast was purchased locally, baked in an oven and diced.

5. Meat Balls

Meat balls were prepared according to MIL Specifications. Changes in formulation were made to improve performance.

6. Chili

Chili was prepared according to MIL Specifications. Canned red kidney beans were used.

7. Chicken and Rice

Prepared according to MIL Specifications. Minor changes in formulations and in processing were made to improve performance.

B. Methods

The methods employed in the preparation and testing of all or part of the materials are described below:

1. Freeze Dehydration

Freeze drying was accomplished using a laboratory Virtis freeze drier. Freeze drying conditions of all samples were kept constant as much as possible. The product was frozen to -40C, vacuum was kept at 30 to 40 microns and the shelf temperature did not exceed 30C.

2. Conditioning

In cases where conditioning and equilibration were used as a pretreatment, the following techniques were employed:

a. Spraying: accomplished with a hand operated atomizer commonly used in microbiological work.

b. Steaming: accomplished in a chamber where steam generated in a different flask was introduced. The residence time of the sample in the chamber was correlated with moisture pick-up.

c. Equilibration: accomplished by placing samples in closed jars or polyethylene bags and storing at the specified temperatures.

3. Compression

In this step, the products were compressed in a plexiglass tube with a hard polyvinyl chloride piston. The use of this transparent material during compression allowed visible observations of the samples during compression. Two instruments were used for compression.

a. Instron: to obtain compression profiles (Force vs. displacement), the Instron was used with the compression rate held constant at 0.1 cm per minute, a maximum compression load of 400 kilograms and dwell time controlled at 0.5 minutes.

b. Carver Press: in cases where the accuracy of the load was not important, and/or higher compression loads than could be achieved with the Instron were required, a Carver Press was used for compression.

4. Testing Procedures

Results given in this report were obtained by following these test procedures:

a. Moisture Content: was determined using a vacuum oven until weights remained constant.

b. Density

- Before Compression: The mass of the freeze dried dices of the animal and combination products needed to fill a known volume was determined. Density was calculated from the following relationship:

$$\text{Density} = \frac{g}{cm^3}$$

- After Compression: Dimensions of the compressed bar were determined with the help of a caliper. Density was calculated from the relationship shown above, using mass in g and volume in cm^3 of the bar.

- Compression Ration:

$$\frac{\text{Density after Compression}}{\text{Density before Compression}}$$

c. Separation Time: Time required for the compressed bar to separate into diced pieces when placed in water at 85C.

d. Color: The color measurements were made on a Hunterlab D25 Color Difference Meter. The following scales were used:

l = Lightness varying from 100 for perfect white to zero for black.

a = reddish when plus, greyish when zero, and greenish when minus.

b = yellowish when plus, greyish when zero, and blueish when minus.

e. Rehydration Time: The time required to rehydrate (as judged visually) a compressed bar of about the same weight in 100 ml of hot water at 85C was measured. Rehydration was always carried out in the same size beakers.

f. Microbial Count: The compressed dehydrated food bars were aseptically ground by hand. The resulting powder was transferred to a sterile Waring Blender containing phosphate buffer. Following homogenization of the product, a serial dilution was made using a phosphate buffered diluent. The dilutions were plated for standard plate counts in accordance with the Bacteriological Analytical Manual of the Food and Drug Administration. All plates were incubated at 37C for 48 hours.

g. Panel for Objective Evaluation: An unstructured taste panel was used. Samples were compared to a rehydrated, freeze dried, uncompressed control on a double rating scale ranging from -3 to +3 with the value of 0 arbitrarily assigned to the control. Four to five judges were involved in these evaluations. The procedure was judged to be sufficiently sensitive since differences between samples were obvious in most cases. Because the observations made by the judges were discriminatory rather than affective, and related directly to a contol to which an arbitrary but definite value was assigned, the procedure was considered to be objective.

Sensory evaluation of stored samples was carried out under controlled conditions, using structured taste panels. Two sensory techniques were applied, a hedonic scale method and a profiling procedure.

The hedonic scale method is an affective technique which measures the level of like or dislike for a product. The scale used was verbally anchored with nine categories ranging from dislike very much (1) to like extremely (9), with the neutral category at point 3 so that more like than dislike categories were used. Samples are presented in succession and no attempt is made to direct the response of the judges who are free to express their feelings about the samples.

Although inferences made on the basis of comparison of average ratings obtained in separate experiments need to be viewed continuously, the relative preference levels among samples tested together are usually found to be very constant from one test to another.

To obtain quantitative and qualitative information for the preference ratings given, a modified profiling technique was used which was developed originally in cooperation with the Quartermaster Food and Container Institute. The procedure is discriminatory and consists of having the judges evaluate individual product attributes on separate nine-point intensity scales ranging from 0 (none) to 8 (very strong or very much). The attributes relate to overall product quality including appearance, texture, and flavor, as well as specific experimental or environmental conditions under test.

In this program, the attributes were tailored to the foods involved and emphasis was placed on color, texture, true flavor, and degree of rehydration. For combination foods, separate attributes were selected for the different components without, however, neglecting overall impressions of product quality.

In contrast to the hedonic scale method, the profiling technique is specific and the samples presented to trained judges in succession are evaluated monadically. References to a control are indirect and without the judges being aware of it.

h. <u>Percent Material Pulverized During Compression and After Rehydration:</u> A method for evaluating the extent of pulverization during compression was developed. The method consists of water separation of the big particles from the small particles and is used only for relative comparison.

INVESTIGATION OF PLASTICIZING AGENTS AND TECHNIQUES

The applicability of various plasticizing agents and techniques for producing compressed bars of different animal and combination products were thoroughly investigated. Depending on the physical characteristics of the product, process modifications were made. Therefore, data in this section are presented product by product.

A. Diced Carrots

1. Materials

Initially, dehydrated diced carrots were used for all experiments after reconstitution in water. This shortcut was used to save preparation time. For the second and later investigational periods, fresh carrots were purchased locally, peeled by hand, and diced. The diced carrots were blanched in steam for seven minutes and were then used in all experiments. The moisture contents of reconstituted dehydrated carrots and freshly blanched, diced carrots were similar. The quality of the fresh, freeze dried carrots was superior to that of the reconstituted carrots, which would be expected.

2. Preliminary Experiments

Preliminary experiments showed that the soaking of blanched, diced carrots in propylene glycol at levels of 5, 10, and 15 percent, followed by freeze drying, showed some promise. However, because of the low boiling point of propylene glycol at the reduced pressures necessary during freeze-drying, the propylene glycol has a tendency to evaporate. Thus, the final product contains no plasticizer and shatters. Substituting glycerol for the propylene glycol was no major improvement, mostly because of poor penetration of the glycerol into the product. Attempts were also made to suspend carrots in a matrix of gelatin, propylene glycol, and water and then to freeze dry the material. Results showed excessive fragmentation of the products during compression.

Other additives such as a carrageenan gel, a carrageenan/CMC gel, corn oil and corn oil with mono and diglycerides were applied to the wet carrots before drying, but the results were discouraging.

Based on these preliminary data, it was hypothesized that the addition of plasticizers to the wet mass was not a promising approach. Therefore, efforts were directed toward the application of plasticizers to the freeze dried carrots.

The purpose of the experiments was to study the potentially most suitable plasticizing agents, including:

- Propylene Glycol
- Glycerol
- Vegetable Oil
- Combinations thereof

The results, which are summarized in Table III (APPENDIX), showed that propylene glycol, when added as a pure substance, was an acceptable plasticizer for diced carrots. In another series of experiments, pure propylene glycol and glycerol were investigated. The results of the experiments are summarized in Table IV (APPENDIX). They indicated that:

- Propylene glycol was the better plasticizing agent from the point of view of product compressibility, with 10 percent propylene glycol being the optimum concentration.
- A propylene glycol concentration of 15 percent resulted in a very noticeable off-taste.

3. Effect of Equilibration Time at Room Temperature with Propylene Glycol as the Plasticizer.

All preliminary experiments were carried out using an equilibration temperature of 50C, which resulted in a discoloration of the carrots. Therefore, subsequent experiments were carried out at room temperature, and a series of experiments was designed to study the effect of time on compressibility. The results which are summarized in Table V (APPENDIX) indicated that there was an improvement in the compressibility of the carrots after an equilibration period of 6 to 24 hours.

4. Other Approaches

From an analysis of the data reported in Tables IV and V (APPENDIX) and from a large number of unsuccessful trials that were conducted subsequently, it was concluded that while propylene glycol at the levels of 7.5 percent to 12.5 percent was encouraging as a plasticizer, it did not perform adequately and imparted an off-flavor to the final product at the level used.

Accordingly, another approach had to be found which would:

- Reduce the final amount of propylene glycol necessary.
- Increase diffusion of the plasticizer into the product so that plasticization could take effect uniformly.

One of the problems encountered with propylene glycol was the fact that equilibration time was very slow and that even relatively high temperatures did not increase the diffusion rate significantly. This was due to the high boiling point and vapor pressure of propylene glycol. Thus, a procedure was required to increase the rate of diffusion into the product.

Based on the knowledge that the water activity, in the presence of propylene glycol is depressed (which constitutes the basis for many intermediate moisture foods), it was decided to increase the diffusion through the use of a water/propylene glycol combination. The most important questions were:

- to identify the method of the water inclusion
- to identify the level of water required.

Preliminary studies were designed to answer these questions.

a. <u>**Spraying with a mixture of propylene glycol/water and compression after varying equilibration conditions.**</u>

The effect of spraying freeze dried carrots with a 7.5 percent solution containing varying amounts of water and equilibrated at different conditions was investigated. The results are summarized in Table VI (APPENDIX). The data indicate that:

- The addition of water, while keeping the total amount of plasticizer constant, decreased fragmentation during compression.

- Heating the product to equilibrate the components resulted in better penetration of the solution into the product.

The results given in Table VII (APPENDIX) present a summary of the data obtained using different equilibration conditions. The results indicate that:

- With increasing water concentration in the plasticizing mixture, there is a general trend toward texture improvement and a decrease in fragmentation.

- Equilibration at 50C for 15 minutes gave the best results while equilibration under vacuum was second best. Compression immediately after application of the plasticizer was found to be worst.

- The final moisture level did not correspond to the expected values based on the amount of water added. This may have been due to the loss of propylene glycol during rehydration.

b. <u>Moisture Application with Steam</u>

In a series of experiments, attempts were made to spray test samples with propylene glycol, followed by steaming them in a steam chamber for a specified period of time and compressing them immediately thereafter.

The steam was generated in situ and transmitted to a chamber into which the carrots had been placed on a fine screen (Figure 2, APPENDIX). To prevent water condensation, it was found necessary to steam the chamber for at least 10 minutes prior to the samples being placed into the chamber.

Steaming in the chamber was allowed to proceed for varying lengths of time to determine moisture pick-up as a function of dwell time in the chamber. Actual moisture pick-up was determined by weight and the data was used to determine approximate residence time necessary to achieve a desired increase in moisture as shown in Figure 3 (APPENDIX).

4. Use of Binders to Prevent Expansion After Compression

During the initial experiments, an undesirable expansion of the compressed carrots was observed within the first 24 hours storage.

Various attempts were made to overcome this problem either by changes in processing technique or by the addition of plasticizers and binders. The experiments are summarized in Tables VIII and IX (APPENDIX).

In general, the experimental evidence was as follows:

- Minimum expansion was achieved with systems containing gelatin as the binder.

- If the carrots were not steamed, expansion could also be held to a minimum.

- As expansion of the compressed carrots was minimized, rehydration time tended to increase.

- The use of a system of binders consisting of a mixture of starch or lactose and carboxymethylcellulose did not have an observable effect on expansion.

- The best results were obtained when a mixture of equal parts propylene glycol and steam were applied at the 10 percent level as the plasticizing agent.

5. Effect of Dwell Time and Pressure

The effect of dwell time and pressure during compression was investigated systematically for the plasticizing and binder systems shown in Table VIII (APPENDIX) under code numbers 100, 101, 102, 203, and 204. The results of the experiments, which are summarized in Table X (APPENDIX), indicated the following:

- Increasing the dwell time up to 30 minutes decreases the expansion effect. Dwell times above 30 minutes yielded no further improvement.
- Increasing the pressure during compression decreased the expansion effect.
- As the expansion effect was minimized, we found an improvement in appearance and mechanical strength. At the same time, there was an increase in rehydration time and a slight reduction in product quality after reconstitution.

B. Diced, Cooked Chicken

1. Materials

Two types of chicken were used for the investigation:

- Commercial diced, cooked frozen chicken
- Fabricated * cooked, diced chicken

2. Preliminary Experiments

Based on the experience gained with carrots, efforts were concentrated on the utilization of propylene glycol as the plasticizing agent. However, the experiments were unsuccessful and fragmentation was very high at all levels of plasticizer applied, and under all equilibration conditions.

* see: "Materials and Methods", 2c), page 13.

Close observation showed that fragmentation occurred mainly along the fiber of the muscle. Thus, attempts were made to increase the cohesiveness of these fibers using procedures, such as an initial soaking in gelatin and gum solutions. However, this approach did not allow satisfactory compression either and was abandoned.

3. Moisture Pick-Up in Steam Chamber

Diced, cooked chicken was freeze dried, and a weighed sample was placed in the already described steam chamber. Moisture pick-up was then determined as a function of dwell time by introducing steam into the chamber. The data are reported in Figure 4 (APPENDIX).

4. Fabrication of Diced Chicken

To reduce fragmentation during compression, diced chicken was fabricated from:

- chicken fibers (shredded chicken muscle pieces)
- chicken emulsion obtained by grinding raw chicken with water
- addition of plasticizers, such as glycerol at various levels and forming the mass into a loaf which was baked, cooled, and diced. The diced chicken was finally freeze-dried and compressed.

A procedure was finally developed for the fabrication of diced chicken similar to chicken loaf. Such a product was considered important because of the problems encountered with commercial cooked, diced chicken:

- Raw chicken muscle (darker meat portion) was blended with 2 parts of water by weight in a Waring Blender at high speed to yield a meat emulsion.

- **Shredded, cooked chicken was blended into the emulsion at the rate of 1.25 parts emulsion to 1 part shredded chicken. Glycerol was added to the mix at levels of 5 percent and 7.5 percent (on a dry weight basis) to act as a plasticizing agent.**

- The mixture was formed into patties and baked for 30 minutes at 190C.

- The baked patties were cooled and diced.

The effect of the level of glycerol added and of a glycerol/gelatin combination on compression and rehydration characteristics was evaluated against a control without additives, and against the commercial product. The results of the tests are summarized in Table XI (APPENDIX). The data indicated that:

- Glycerol added at a level of 4 percent (calculated on wet weight) was sufficient to plasticize the chicken provided a steaming procedure was used.

- Higher levels of glycerol did not improve functionality, but led to an increase in sweetness and aftertaste.

- A moisture content of 5.7 percent was sufficient to render the diced chicken compressible.

In a second series of experiments, the chicken was cooked for 10 minutes in 2.5 parts of water (250 grams of water per 100 grams of chicken) and levels of glycerol ranging from 10 grams to 25 grams in increments of 5 grams. The mixtures were cooled in the refrigerator for 2 hours before the residue was freeze dried.

The freeze dried samples were compressed at 6.9×10^6 Pa with and without steaming, as shown in Table XII (APPENDIX). The data indicated that:

- Higher glycerol levels gave better product performance.

- A required minimum amount of steam has to be added prior to compression to give plasticity.

- Improvements in performance were observed at a moisture content as low as 3.8 percent for the compressed chicken.

5. New Plasticizing Techniques

a) Propylene Glycol Vaporization

Freeze dried chicken was placed in vacuum containers and propylene glycol was added at levels to yield concentrations of 5 percent and 7.5 percent in the chicken after equilibration. The containers were evacuated to 9.8×10^4 Pa, heated to 50C, and held under those conditions for four hours. Finally, the flasks were cooled to ambient temperature. The chicken was compressed at 6.9×10^6 Pa.

After rehydration in excess water, the chicken was evaluated for the effect of the propylene glycol vaporization technique on the compression and rehydration characteristics. It was found that the propylene glycol had not penetrated the tissue to any extent and was concentrated in areas of direct contact.

b) Glycerol Vaporization

Diced, cooked chicken was placed on a layer of glycerol in the tray of the freeze drier. The quantity of glycerol was calculated as 10 percent glycerol (on dry weight) after equilibration. The chicken was freeze dried and compressed at 6.9×10^6 Pa without steam and with steam at the 2.5, 5.0, and 7.5 percent level.

On rehydration in an excess of water, the product was evaluated to determine the effect of the glycerol applied under the above experimental conditions on compression and rehydration. It was found that the glycerol concentrated in the tissue at the points of contact and did not penetrate to any extent.

c) Addition of Glycerol/Ethanol Solution

Diced, cooked, freeze dried chicken was treated with glycerol/ethanol solutions of varying concentrations to obtain a level of 5, 7.5, and 10 percent glycerol in the chicken on a dry weight basis.

The alcohol was evaporated from the sample at 50C to a constant weight which took six hours. The dry sample was compressed with varying levels of steam (0, 2.5, 5 percent) at 6.9×10^6 Pa.

After rehydration in excess water at 85C, the chicken was evaluated by an informal panel. The results of the evaluation are summarized in Table XIII (APPENDIX) and the data indicated that:

- An acceptable, reversibly compressed freeze dried chicken could be obtained using ethanol as a carrier to allow the glycerol to penetrate into the tissues.
- Evaporation time and off-flavors, due to incomplete ethanol removal, appear to make this approach impractical.

C. Cooked Shrimp

1. Materials

Frozen, raw shrimp were purchased from a food broker. The shrimp, which were in the 80-120 count range, were cooked in boiling water for approximately five minutes before use.

2. Preliminary Experiments

Preliminary experiments showed that shrimps tend to behave in a manner similar to diced carrots. The results summarized in Table XIV (APPENDIX) show the effect of various plasticizing agents on the compression and rehydration characteristics of the shrimps. The data indicated that propylene glycol was superior to oil as a plasticizing agent, probably because of the hydrophobic character of oil.

3. Mixtures of Propylene Glycol/Water and Equilibration Conditions

The results shown in Table XV (APPENDIX) indicate that successful reversible compression may be achieved with a 1:1 mixture of propylene glycol and water applied at the 10 percent level. A decrease in the water content resulted in a decrease in the compression rehydration performance.

The results indicate that shrimps can be compressed successfully using this technique and that the rehydrated product is very similar to the freeze dried, reconstituted product that has not been compressed.

4. Moisture Pick-Up in Steam Chamber

The cooked shrimp were freeze dried and placed in the previously described steam chamber. Steam was introduced and the increase in moisture of the dry shrimp was determined as function of dwell time by measuring the shrimps' increase in weight as shown in Figure 5 (APPENDIX).

5. Effect of Equilibration Time on Product Performance

Freeze dried shrimp were sprayed with 5 percent propylene glycol (based on dry weight) and exposed to steam until the moisture was between 3 percent and 3.9 percent. They were then compressed immediately. In correlative experiments, the shrimp were allowed to equilibrate for 15, 30, and 60 minutes at room temperature before compression as summarized in Table XVI (APPENDIX). The data indicated:

- Equilibration time did not appear to affect product performance.
- There was no significant correlation between compressibility and rehydration characteristics.
- To be acceptable, the moisture content should not be lower than 3.9 percent.

b) Glycerol/Water Plasticizing Technique

Shrimps were boiled in a 15 percent glycerol solution for 5 minutes and held under refrigeration for seventeen hours. The glycerol solution was drained and the shrimp, freeze dried and compressed at 6.0×10^6 Pa with 2.5 and 5.0 percent steam.

The samples were rehydrated in excess water at 85C and evaluated for compressibility and rehydration characteristics. The tests indicated:

- Glycerol imparted excellent compression characteristics to freeze dried shrimp with no observable breakage.

- Samples prepared in this manner rehydrated too slowly (30 to 60 minutes) to be acceptable.

In general, shrimps were easier to compress and involved fewer technical problems than chicken.

D. Meat Balls

1. Materials

Meat balls were prepared according to MIL specifications. The only modification made was to increase the salt level by 50 percent to improve palatability.

2. Preliminary Experiments

Table XVII (APPENDIX) summarizes the basic formulations evaluated in our preliminary experiments. The method of preparation was as follows:

a. All ingredients, except the meat and egg albumin, were mixed with the water and heated to 82C.

b. The meat was then added and mixed in. From this mass, meat balls weighing about 8 g each were formed by hand.

c. The meat balls were fried in a pan with soybean oil at 190C for 1 minute and 45 seconds.

d. The fried meat balls were frozen and freeze dried.

The freeze dried meat balls were sprayed with 5 percent propylene glycol (based on dry weight) and steamed with an additional 5 percent of water (based on dry weight).

The results shown in Table XVIII (APPENDIX) indicate that the inclusion of glycerol as part of the formula was necessary to obtain reversible compression. All other formulations resulted in flat meat balls which did not rehydrate to their original shape.

3. Effect of Glycerol on Product Performance

Several meat ball formulations, which differed in the proportion of salt (1 to 2 percent) and glycerol (3.2 to 7 percent), were prepared as shown in Table XIX (APPENDIX). The meat balls were fried, freeze dried, and exposed to steam before they were compressed at 6.1×10^6 Pa with zero dwell time. The results are summarized in Table XX (APPENDIX) and the data showed that:

- Increased glycerol levels yielded products with better compression and rehydration characteristics.
- A salt level of 1.5 percent was indicated to reduce the apparent sweetness of 7 percent glycerol to an acceptable level.
- During compression, an exudate appeared which was believed to be excess fat or oil.

An attempt was made to look at the origin of the exudate. The fat content of the meat balls was determined before and after compression using a Soxhlet apparatus. The results showed a decrease in fat content from 33.2 percent before compression to 20.9 percent after compression. Experiments were conducted to eliminate this problem.

It was found that switching from ground chuck to ground sirloin obviated the exudate almost completely. The reason was believed to be a reduction in fat content when switching from chuck to sirloin. Based on extractions in a Soxhlet apparatus before compression, the respective levels of fat were 33.2 percent and 22.6 percent.

4. Shortening of Rehydration Time

Surface active agents were investigated for reducing the rehydration time of meat balls. Tween 60 was found very effective. Addition of 0.039 percent Tween 60 to the formula reduced rehydration time by one-third to one-half.

E. Chicken and Rice

1. Materials

The basic formulation for the chicken and rice and the chicken gravy mix are given in Tables XXI and XXII (APPENDIX). The formulations were derived from the corresponding MIL standard. The chicken used was commercial, diced, cooked, frozen chicken.

To start, the moisture content of the dinners and individual components was determined by vacuum drying to constant weight. The figures were as follows:

Diced cooked chicken:	66.5%
Cooked converted rice:	70.0%
Chicken and rice dinner:	67.0%

2. Preliminary Experiments

Initial experiments were conducted to assess the effect of the addition of glycerol to the whole freeze-dried dinner on its compressibility. Glycerol was added to yield a final concentration of 7.5 percent on a dry weight basis. The glycerol-containing, freeze dried mix was steamed until the moisture increase was 2.5 percent, compressed, and stored.

The results indicated that the product was inferior to the control because the cellular structure of the natural components had been damaged during compression.

3. Effect of Propylene Glycol

Freeze dried, diced chicken and freeze dried, cooked rice were sprayed with propylene glycol at concentrations ranging from 2.75 percent to 10 percent (based on dry weight). The samples were then exposed to steam, combined with the remaining ingredients in the compression cell, and compressed. The data indicated that:

- the maximum acceptable level of propylene glycol was 5.6 percent. At higher levels, the off-flavor was objectionable.

- only some treatments yielded a product with satisfactory compression and rehydration characteristics.

The major technical problems were traced to the rice and the off-flavor due to the propylene glycol. Therefore, additional experiments were designed to overcome these difficulties.

4. Cooking with Rice in Water/Glycerol Solutions

Rice was cooked in a water/glycerol solution with the glycerol concentration calculated at 7.5 percent, based on the dry weight of the rice. The cooked rice was freeze-dried, combined with freeze dried chicken, and exposed to steam until the moisture increase was 2.5 percent. The other ingredients were added and the whole dinner was compressed. To increase the mechanical strength of the compressed product, the vegetable oil was replaced with a hydrogenated shortening.

The dinner was evaluated after reconstitution and was found to be comparable to a freeze-dried control that had not been compressed in appearance and texture. However, there was still a slightly sweet aftertaste, and rehydration time was longer than the specified 20 minutes.

To increase the rate of rehydration, a surface active agent (Tween 60) was added to the shortening at a concentration of 0.1 percent. This modification reduced rehydration time to 15 minutes without any deleterious effects.

Finally, the levels of glycerol and steam were optimized for the storage tests that were conducted. Glycerol concentrations studied were in the 4.5 percent to 7.5 percent range, and steam levels in the 4 percent to 6 percent range, calculated as moisture content of the dry dinner.

F. Chili con Carne

1. Materials

Basic chili formulations are presented in Tables XXIII and XXIV (APPENDIX). Table XXIII also contains directions for preparation. It should be noted that the red kidney beans were soaked first overnight in water, and cooked for 30 minutes before they were used.

2. Preliminary Experiments

Initial experiments indicated that the most sensitive component was the beans which during and even before compression had a tendency to peel. However, since the current freeze dried chili used as a Long Range Patrol ration exhibits the same peeling effect, it was concluded that the acceptability of the product is not affected by this phenomenon.

In view of the sensitivity of the beans, it was decided to apply all pretreatments directly to the beans.

3. Soak Equilibration in Glycerol Solutions

Beans were soaked in water containing glycerol at concentrations of 2.5, 5, and 10.75 percent, based on a calculated equilibrium level of the total chili mix, overnight. They were cooked in the same solution cooled to ambient temperature, separated from the supernatant liquid, and freeze dried.

The meat was cooked in water, together with the seasoning mix, the tomato paste was added, and the total mix was freeze dried.

Although no steam was used initially as a plasticizing agent, subsequent experiments were carried out where the beans were exposed to steam until a selected increase in moisture had been achieved. The beans were combined with the other ingredients after steaming and compressed. The results of the experiments showed that:

- the chili could be compressed with minimum shattering of the beans if glycerol was applied at the 5 to 10 percent concentration range.

  However, the compressed products had limited mechanical strength and a tendency to expand during storage. Also, rehydration time was slow and there was a sweet aftertaste.

- When lower concentrations of glycerol were used, the beans suffered extensive mechanical damage, although mechanical strength of the compressed product was improved. Rehydration time did not improve.

To achieve better product performance, additional experiments were designed in which the beans were steamed, but care was taken to keep the moisture content of the complete chili below 3.6 percent. Also, 0.1 percent of a surface active agent (Tween 60) was introduced into the formula which reduced rehydration time significantly.

G. Beef Stew

1. Materials

The basic beef stew formulation, including the seasoning mix, was derived from the corresponding MIL standard. It is summarized in Table XXV and XXVI (APPENDIX).

The ingredients listed were mixed, brought to a boil, and simmered for 5 minutes.

2. Preliminary Experiments

Initial experiments were concentrated on adding glycerol to the total product mix during the preparation step, followed by freeze drying and compression. It was found that the process resulted in damage to the stew. The potatoes appeared to be most seriously damaged, followed by the peas, the carrots, and the meat, in that order.

Therefore, subsequent experiments were designed to include exposure of the total product mix to steam until a moisture increase of 2.5 percent had been achieved. The extra processing step improved the texture of the peas, carrots, and meat, but did not appear to reduce the damage to the potatoes. Also, steaming increased rehydration time significantly and seemed to make the sweet aftertaste more noticeable, although it was not judged to be objectionable.

3. Addition of Glycerol Sensitive Ingredients

Only very preliminary experiments were carried out. Since potatoes seemed to present the greatest technical problem, possibly because of their particular cellular structure or their lack of cellular structure in stew, emphasis was placed on reducing the damage to the potatoes and peas. Attempts have been made to incorporate glycerol into the potatoes and the peas. Efforts in this direction did not yield satisfactory products.

H. Diced Beef

1. Preliminary Experiments

Preliminary experiments showed that the problems encountered with beef were not associated with its compression behavior and/or the extent of fragmentation during compression (using propylene glycol as the plasticizing agent). Rather, the problems were caused by the high fat content of the meat (15 percent on dry weight basis), which resulted in:

- development of rancidity during storage of the freeze dried beef.
- recovery of the compressed mass immediately after release of compression pressure.

2. New Plasticizing Techniques

a) Glycerol Soak

Diced, cooked beef (eye round) was allowed to soak in glycerol solutions for 17 hours at refrigerator temperature. The beef was drained, freeze dried, treated with various levels of steam, and compressed at 3.4×10^6 Pa with a dwell time of 3 minutes.

The rehydrated beef was evaluated and it was found that:

- reversible compression could be achieved by soaking in 5 percent glycerol and steaming to an increase in moisture of 5 percent.
- rehydration time was too slow; it took 30 minutes.
- glycerol levels above 5 percent yielded an acceptable bar, but a sweet taste was apparent.

b) Addition of Surface Active Agent

A surface active agent (Tween 60) was added to the soak solutions at a level of 0.15 percent. Processing otherwise remained the same.

It was found that the Tween 60 reduced the rehydration time to 20 minutes.

c) Application of Heat

During the experiments, it was observed that samples which were steamed and allowed to equilibrate at ambient temperature did not compress as well as samples that were compressed immediately after steaming.

Therefore, a series of experiments was conducted in which the steamed beef was brought to temperatures of 65C and 82C in closed containers immediately before compression.

Evaluation of rehydrated samples indicated that heating before compression resulted in diced beef that showed less internal damage than any samples not treated in this manner.

FORMULA OPTIMIZATION

A. Diced, Cooked Chicken

Diced, cooked frozen chicken was boiled in an equal weight of 10 and 15 percent glycerol solutions and refrigerated for 17 hours for equilibration. After equilibration, the chicken was drained and freeze dried.

The diced, glycerol-containing chicken was treated with 4 percent and 5 percent steam and compressed at 6.9×10^6 Pa.

Samples were rehydrated in excess water (10 parts water to 1 part compressed chicken) at 85C, and presented to the trained sensory panel for evaluation. The results of the tests are summarized in Table XXVII (APPENDIX). Based on the results of the profile tests (high scores for desirable, low scores for undesirable attributes), the following treatments were considered best:

- boiling in a 10 percent glycerol solution and application of 5 percent steam.
- boiling in a 15 percent glycerol solution and application of 4 percent steam.

B. Shrimp

The optimum treatment and formula were selected based on the information discussed under Section V entitled "Investigation of Plasticizing Agents and Techniques".

The propylene glycol/steam plasticizing technique was judged to be best, using the following treatment conditions:

- 5 percent propylene glycol spray, steamed to a moisture increase of 5 percent.
- (see Investigation of Plasticizing Agents and Techniques, 5 a), page 27).

C. Meat Balls

Formula modifications containing 0.04 percent of the surface active agent, Tween 60, were prepared by varying the glycerol content and the amount of steam applied. Table XXVIII (APPENDIX) summarizes the formulae that were formed into meat balls, freeze dried, and compressed at 5.2×10^6 Pa with a dwell time of 3 minutes.

The samples were rehydrated in excess water at 85C and evaluated by the trained sensory panel. The results of the test are summarized in Table XXIX (APPENDIX). Based on the results of the tests, the following were judged to be optimum:

- pretreatment with 5 percent glycerol and steamed to a 4 percent moisture content.
    - acceptably low sweetness; good rehydration
- pretreatment with 7 percent glycerol and steamed to a 6 percent moisture content.
    - excellent appearance, low rubberiness

D. Chicken and Rice

Experiments were conducted to determine optimum levels of glycerol and steam to be incorporated into the chicken and rice dinner.

Glycerol was added to the rice at levels ranging from 4.5 percent to 7.5 percent. The glycerol containing rice was combined with the freeze dried chicken and seasonings. The mixture was exposed to steam until moisture levels of 4, 5, and 6 percent were reached, and then compressed.

The samples were rehydrated and evaluated by sensory techniques. The results of the test are summarized in Table XXX (APPENDIX). Based on the results of the tests, the formulae shown as 201 and 202 in Table XXXI (Appendix) were considered to be most suitable. Specifically:

- a 7 percent glycerol spray followed by a steaming to a moisture content of 5 percent.
- a 5 percent glycerol spray followed by a steaming to a moisture content of 5 percent.

E. Chili con Carne

Preliminary experiments had indicated that the treatment of the kidney beans was the crucial factor to the reversible compression of chili con carne. Further experiments, thus, were concentrated on finding optimum conditions for plasticizing kidney beans.

It was found that both glycerol and steam were required to reach a suitable state of plasticity. Glycerol levels had to be above 5 percent to prevent fracturing the beans and below 10.5 percent to achieve compression. The optimum moisture level achieved by steaming was found to be 9 percent.

Samples were prepared by soaking the beans in glyc erol solutions until a suitable glycerol level (5 to 10.5 percent) was reached, calculated on dry weight. The soaked beans were steamed, mixed with the remaining components that had been freeze dried, and compressed.

The chili con carne was rehydrated in 2 parts water at 85C and evaluated by sensory panel techniques. The results are summarized in Table XXXII (APPENDIX). Based on the results of the tests, optimum plasticization was achieved with:

- soaking in 5 percent glycerol, followed by steaming to a 4 percent moisture content

- soaking in 2.5 percent glycerol, followed by steaming to a 4 percent moisture content.

It should be noted that plasticizing agents were added to the kidney beans only, but that the above values are calculated for the whole chili con carne. The formulae used are shown in Table XXXIII (APPENDIX).

F. Beef Stew

While carrying out preliminary experiments, it had been found that the ingredients of beef stew were affected differently by compression and efforts to pretreat, freeze dry, and compress beef stew as a unit were not successful. Therefore, pretreatment was approached differently this time, and each component was processed separately.

- <u>Potatoes</u>

Experiments were conducted to form a skin around diced potatoes by deep-fat frying them to a point where case hardening could be observed, but no color appeared as yet. Subsequent experiments indicated that reversibly compressible potato dices could be developed by:

- deep fat frying dices at 190C for 75 seconds. Boiling the potatoes in water for 60 seconds to remove excess oil, draining the potatoes, and freeze drying them.

- steam was added to increase the moisture by 15 percent and the dices were compressed.

The oil removal step was necessary because it was found that residual oil was a problem in freeze drying. The relatively high moisture content of the compressed potato dices was not judged to be a handicap because the moisture tended to equilibrate throughout the beef stew and, hence, only accounted for about 2 percent moisture in the final product.

- <u>Peas</u>

Frozen blanched peas were pretreated by soaking in glycerol solutions. They were freeze-dried and treated with steam to reach the required degree of plasticity before compression.

Evaluation of several samples treated with varying concentrations of glycerol and steam showed that the following treatment was best:

- soaking in a 5 percent glycerol solution (on a dry weight basis) and steaming to an increase in moisture content of 5 percent.

- <u>Carrots</u>

It was found that diced, freeze dried carrots behaved well in beef stew if treated with steam to an increase in moisture content of 5 percent.

- **Beef**

Experiments were conducted with diced, cooked beef for both the beef stew and the diced beef bar.

Optimum treatment conditions were found to be as follows:

- beef was soaked in a 5 percent glycerol solution, 0.15 percent Tween 60 was added, and the beef was steamed to an increase in moisture content of 5 percent.

- beef was soaked in a 10 percent glycerol solution, 0.15 percent Tween 60 was added, and the beef was steamed to an increase in moisture content of 2 percent.

The samples were heated to 82C before compression. Optimum formulae are summarized in Table XXXIV (APPENDIX).

RESULTS OF STORAGE TESTS

A. Diced Carrots

1. Processing

Blanched, diced carrots were freeze dried, pretreated for plasticity and compressed. The following pretreatments were used:

- 3.75% propylene glycol spray, steamed to a moisture increase of 3.75%
- 7.5% propylene glycol spray, steamed to a moisture increase of 2.5%
- 5% water spray followed by vacuum equilibration
- propylene glycol treatment under vacuum at 50C to a calculated 10% pick-up.

The compressed carrots were packed in pouches, flushed with nitrogen, sealed, and stored. The storage time before initial evaluation was a maximum of three days.

2. Objective Evaluation

The results of the physical and microbiological evaluation tests after processing and storage are summarized in Tables XXXV, XXXVI (APPENDIX). The data indicated that:

- Moisture Content: the moisture content of the blanched carrots averaged 86.5 percent, that of the dehydrated compressed product ranged from 5.2 to 6.4 percent. The moisture content of the reconstituted carrots ranged from 85.1 to 89.0 percent.

During storage, a slight reduction in the moisture content was noticed indicating that the packages were not completely air tight or continued to equilibrate.

The moisture determinations of the dried products may have given high readings because propylene glycol may have been lost during the determinations.

- Compression: using a pressure of 3.44×10^6 Pa and a 30 seconds dwell time, the density increased from approximately 0.1 gram/cc before compression to 1.0 gram/cc after compression. The compression density during storage decreased to 0.6-0.7 corresponding to about an expansion of 40 to 65 %.

- Rehydration Time: using 15 parts of water for each part of compressed carrots and a water temperature of 85C, but no agitation, rehydration times ranged from 5 minutes to 8.3 minutes. The rehydration time tended to increase slightly with the time of storage.

- Color: colors were determined using a Hunter Color Meter. There was little difference between the samples tested.

- Microbial Counts: average counts were about 1000 microorganisms per gram at zero storage time. They were identified to be of the Bacillus species and were probably introduced during handling. During storage, microbial counts decreased to 250 or less per gram.

3. Sensory Evaluation

A panel of trained and experienced judges was used for all tests. The results of the sensory evaluation by means of hedonic scale ratings are summarized in Table XXXVII (APPENDIX).

The data indicated that the treated, compressed carrots were equally well-liked as the control after storage at -18C over a period of 90 days. At a storage temperature of 28C, the treated, compressed carrots were actually preferred over the control after 90 days, when a pretreatment with 7.5 percent propylene glycol and 2.5 percent steam was used.

At a storage temperature of 38C, the compressed diced carrots were found to be less acceptable after 90 days. After 60 days storage, pretreatment with 3.75 percent propylene glycol and 3.75 percent steam yielded, however, only marginally less acceptable compressed carrots.

In order to determine the reasons for the hedonic scale ratings, a second series of sensory panel tests was conducted with profiling technique described under "Materials and Methods". The results of the tests are summarized in Table XXXVIII (APPENDIX).

The data indicates that the compressed samples had profiles after storage at 30, 60, and 90 days at the higher storage temperatures that would make them less acceptable, although the control also deteriorated significantly after 60 days storage at 38C. Indeed, after storage at 28C for 90 days, the control had deteriorated more than the compressed samples. Deterioration was evidenced by dis coloration, the appearance of an off-flavor and a stale note, and by an increase in undesirable aftertaste. While neither pretreatment was entirely satisfactory over the entire storage period at all storage temperature, the combination of 3.75 percent propylene glycol and 3.75 percent steam yielded rehydrated carrots with more acceptable profiles.

B. Shrimp

1. Processing

Cooked shrimp were freeze dried, pretreated for plasticity, and compressed. The following pretreatments were used:

- 5% propylene glycol spray, steamed to a moisture increase of 5%.
- 7.5% propylene glycol spray, steamed to a moisture increase of 2.5%.
- spraying with a 3:1 propylene glycol/water solution for a total pick-up of 12.5%. This was followed by heating at 50C for 15 minutes.

The compressed shrimp were sealed in pouches under nitrogen and stored for a few days at ambient temperature.

2. Objective Evaluation

The results of the physical and microbiological evaluation tests after processing and storage are summarized in Tables XXXIX and XXXX (APPENDIX). The data indicated that:

- Moisture Content: Initial moisture content was determined to be 74.1 percent (average); after compression, it ranged from 5.5 to 8.1 percent. The moisture of the reconstituted shrimp was in the 71.7 to 76.3 percent range. A reduction in the moisture contents of the compressed bar was noticed during storage.

- Compression: Using a pressure of 6.9×10^6 Pa and a dwell time of 60 seconds, the density increased from about 0.2 g/cc before compression to 0.89 g/cc after compression. This corresponds to a compression ratio of 4 to 1. During storage the density of the compressed bars decreased to 0.72 - 0.78, corresponding to a 7 - 20 percent expansion.

- Rehydration Time: Using approximately the same conditions that were used for carrots, rehydration times ranged from 8.5 minutes (7.5% propylene glycol, 2.5% steam pretreatment) to 17 minutes. No significant change in the rehydration time of the product was noticed during storage.

- Color: Differences in color between the samples under test were insignificant.

- Microbial Counts: Average counts were less than 100 per gram. Microbial counts of stored shrimp remained low during the entire storage period.

3. Sensory Evaluation

The results of the sensory evaluation, by means of hedonic scale ratings, are summarized in Table XXXXI (APPENDIX).

The data indicated that the compressed shrimp were liked at least as well as the controls over the entire 90 day storage period, at all three storage temperatures (-18C, 28C, 38C).

To support the hedonic scale ratings, a second series of sensory panel tests was conducted by means of the profiling technique described in the "Materials and Methods" section. The results of the tests are summarized in Table XXXXII (APPENDIX).

Considering the circumstances of the test situation, the profiles are remarkably similar. After storage at 38C, a slight increase in off-flavor was found in the compressed shrimp which was, however, offset by a reduction in toughness. Of the two pretreatments applied, treatment with 5 percent propylene glycol and 5 percent steam appeared to yield compressed shrimps with a very slightly more acceptable profile.

C. Diced Cooked Chicken

1. Processing

Diced cooked chicken was pretreated for plasticity, freeze dried, and compressed. The following pretreatments were used:

- 10% glycerol infusion, steamed to a moisture increase of 4%.
- 15% glycerol infusion, steamed to a moisture increase of 5%.

The compressed chicken was packed in pouches, flushed with nitrogen, sealed, and stored at ambient temperature. The storage time before evaluation was a maximum of three days.

2. Objective Evaluation

The results of the physical and microbiological evaluation tests after processing and storage are summarized in Tables XXXXIII and XXXXIV (APPENDIX).

The data indicated that:

- <u>Moisture Content:</u> The moisture content of the dehydrated compressed chicken ranged from 5.7% to 6.0%. No significant difference in the moisture content of compressed chicken was noticed during storage.

- <u>Compression:</u> Using a pressure of 5.2 x 10^6 Pa and a dwell time of 2 minutes, the density increased from approximately 0.3 g/cc before compression to 1.2 g/cc after compression. During storage, the compressed bars expanded from 20 to 50 percent.

- <u>Rehydration Time:</u> Using 10 parts of water for each part of compressed chicken and a water temperature of 85C, but no agitation, rehydration time was 15 minutes. The rehydration time of some of the stored chicken samples increased slightly during 3 month storage.

- <u>Microbial Counts:</u> Average counts were less than 10,000 microorganisms per gram. During storage the microbial counts of the samples decreased initially, then increased, but not to significant levels.

3. <u>Sensory Evaluation</u>

The results of the sensory evaluation by means of hedonic scale ratings are summarized in Table XXXXV (APPENDIX).

The data indicated that at -18C storage temperature, the compressed samples were as well liked as the control after 90 days. At the higher storage temperatures, the compressed chicken samples were found to deteriorate more rapidly. However, after 90 days at 38C storage temperature, the control had deteriorated to a point where it was only marginally better than the compressed experimental samples, especially the one pretreated with 10 percent glycerol and 0.75 minutes (4%) steam. Thus, the difference was actually more pronounced at 28C storage temperature where the control was substantially better liked after all three storage periods, probably because it deteriorated very little, while the compressed diced chicken was liked less even at the beginning of the storage test.

In order to determine the specific reasons for the hedonic scale ratings, a second series of sensory panel tests was conducted, using the modified profiling technique described previously. The results of the tests are summarized in Table XXXXVI (APPENDIX).

From the profiles obtained, it could be seen that the major differences were found in appearance, off-flavor, the stale note, undesirable after-taste, and overall quality. It was interesting to note that, except for appearance (the compressed samples browned badly), the differences in individual attributes between the control and the compressed samples tended to be smaller after 90 days at the higher storage temperatures than at the shorter storage intervals. The reason was that the control also deteriorated after 90 days.

Of the two pretreatments applied, the treatment with 10 percent glycerol and 0.75 minutes steam yielded a superior compressed diced, cooked chicken.

D. Meat Balls

1. Processing

Glycerol was incorporated into the meatball formulation as a plasticizer; the meat balls were fried, freeze dried, steamed for additional plasticity, and compressed. The following pretreatments were used, based on the results of previous tests:

- 10% glycerol in the formula (dry weight), steamed to a moisture increase of 4% before compression.

- 15% glycerol in the formula, steamed to a moisture content of 5% before compression.

The compressed meat balls were packed in pouches, flushed with nitrogen, sealed, and stored. Maximum storage time before evaluation was three days at ambient temperature.

2. Objective Evaluation

The results of the physical and microbiological evaluation tests after processing and storage are summarized in Tables XXXXVII and XXXXVIII (APPENDIX).

The data indicated that:

- Moisture Content: The moisture content of the dehydrated compressed meat balls ranged from 4.1 percent to 5.3 percent. The moisture content did not change significantly during storage.

- Compression: Using a pressure of 3.44×10^6 Pa and a 3 minute dwell time, the density increased from 0.3 gram/cc before compression to 1.6 gram/cc after compression. The compressed meat balls did not expand to any significant extent during storage.

- Rehydration Time: Using 10 parts of water for each part of compressed meat balls and a water temperature of 85C, but no agitation, rehydration time was approximately 6 minutes. During storage the rehydration time increased substantially, ranging from 12 - 20 minutes.

- Microbial Counts: average counts were 1.5×10^6 per gram. The microbial counts decreased considerably during storage. Initial high counts may have been due to the manual handling involved in the laboratory preparation of meat balls.

3. Sensory Evaluation

The results of the sensory panel evaluation by means of hedonic scale ratings are summarized in Table IL (APPENDIX).

The data indicates that up to a storage time of 60 days, the compressed meat balls were liked as well as the control at all three storage temperatures, although the results tended to be more variable than with the other foods investigated. After 90 days storage, the compressed samples were comparable to the control at the lower storage temperatures.

At a storage temperature of 38C, the experimental samples were liked significantly less. Again, the results varied more than usual. Generally, the pretreatment with 10 percent glycerol and 0.75 minutes steam appeared to yield a superior compressed meat ball.

To elucidate the reasons for the hedonic scale ratings and the variability of the results, a second series of sensory panel tests was conducted using the previously described modified profiling technique. The results of the tests are summarized in Table L (APPENDIX).

The profiles show that the differences in acceptability were primarily due to appearance, sweetness, undesirable aftertaste, rubberiness, and completeness of rehydration. The profiles also may explain the variability in the hedonic scale ratings. The data relating to undesirable aftertaste and rubbery texture appear to show almost random variability, possibly because of variations from batch to batch, thus indicating that processing and handling during processing need to be improved further.

E. Chicken and Rice

1. Processing

Pretreatment with glycerol was applied to the rice. Moisture content was adjusted with steam for the whole dinner. The specific treatments utilized were as follows, calculated on the dry weight of the dinner:

- 7% glycerol in the rice; the whole dinner steamed to a moisture content of 5%.

- 5% glycerol in the rice; the whole dinner steamed to a moisture content of 5%.

The compressed chicken and rice dinners were packed in pouches, flushed with nitrogen, sealed, and stored at ambient temperature. Storage time before evaluation was a maximum of three days.

2. Objective Evaluation

The results of the physical and microbiological evaluation tests after processing and storage are summarized in Tables LI and LII.

The data indicated that:

- <u>Moisture Content:</u> The moisture content of the compressed dinner was 5.0 percent. It did not change significantly during the 90 days storage period.

- <u>Compression:</u> Using a pressure of 3.45×10^6 Pa and a 3 minute dwell time, the density increased from 0.28 gram/cc to 0.94 gram/cc after compression. During storage, the density of the compressed bars decreased slightly, ranging from 0.80 0.85.

- <u>Rehydration Time:</u> Using 2 parts of water for each part of dinner and a water temperature of 85C, but no agitation, rehydration time was 20 minutes. The rehydration time remained 20 minutes during storage.

- <u>Microbial Counts:</u> Standard aerobic counts were taken in the usual manner. All counts were less than 10,000 microorganisms per gram. Except for one sample, the microbial counts remained low during the entire 90 day storage period. One sample, after 1 month storage, had a count higher than 3 million. It was apparently due to post processing contamination in that package.

3. <u>Sensory Evaluation</u>

The results of the sensory panel evaluation by means of hedonic scale ratings are summarized in Table LIII (APPENDIX).

The data indicates that the control was preferred to the compressed samples after all storage times at the 28C and 38C storage temperatures. At a storage temperature of -18C, the experimental samples were liked as well as the control, even after 90 days storage. It was interesting to note that the control deteriorated very little over the storage period.

To determine the reasons for the hedonic scale ratings, a second series of sensory panel tests was conducted using the previously described modified profiling technique. The results are summarized in Table LIV (APPENDIX).

The profiles indicate that the major differences were in appearance, chicken flavor level, flavor balance, off-flavor, and staleness. The compressed samples and, particularly, the chicken, lost their natural appearance and the off-flavor which developed tended to mask the chicken flavor and upset the total flavor balance. As would be expected, the differences in the attributes evaluated became greater at the higher storage temperatures, particularly at 38C. It should, however, be noted that the compression did not lead to a tougher product and that the rice grains remained distinct even at a storage temperature of 38C. It was difficult to discern a trend in the effect of the pretreatment. Treatment with 5 percent glycerol was, perhaps, marginally more advantageous, albeit not under all storage conditions.

F. Chili con Carne

1. Processing

Glycerol was infused into the kidney beans prior to freeze drying. The freeze dried beans were also steamed before being combined with the remainder of the ingredients which had been freeze dried separately. The total dinner was compressed together. The pretreatments used for the storage samples were as follows, based on the weight of the dinner:

- infusion of 5% glycerol and steaming to a 5% increase in moisture content.
- infusion of 2.5% glycerol and steaming to a 4% increase in moisture content.

The compressed chili con carne was packed in pouches, flushed with nitrogen, sealed, and stored at ambient temperature. The storage time before evaluation was a maximum of three days.

2. Objective Evaluation

The results of the physical and microbiological evaluation tests after processing and storage are summarized in Table LV and LVI (APPENDIX). The data indicated that:

- Moisture Content: The moisture content of the compressed dinner was 4.0 percent. No significant change in the moisture content of the compressed products was noticed during storage.

- Compression: Using a pressure of 3.44×10^6Pa and a 3 minute dwell time, the density increased from 0.3 grams/cc before compression to 1.26 grams/cc after compression. During storage, the compressed bars expanded somewhat, expansion ranging from 20 - 35 percent.

- Rehydration Time: Using 2 parts of water for each part of the dinner, and a water temperature of 85C, but no agitation, rehydration time was 19 minutes. The rehydration time did not change significantly during storage.

- Microbial Counts: Standard aerobic counts were taken in the usual manner. All counts were less than 10,000 microorganisms per gram. During storage, the microbial counts generally decreased further.

3. Sensory Evaluation

The results of the sensory evaluation by means of hedonic scale ratings are summarized in Table LVII (APPENDIX).

The data indicated that the compressed samples were actually preferred to the control over the entire storage period at storage temperatures of -18C and 28C. At a storage temperature of 38C, the control was liked better after 30 days and 60 days storage, while the difference had become minimal after 90 days storage, probably because the control had deteriorated as much as the experimental samples by that time.

To substantiate the hedonic scale ratings, a second series of sensory panel tests was conducted using the previously described modified profiling technique. The results of the tests are summarized in Table LVIII (APPENDIX).

The profiles obtained uncovered some rather interesting facts which explain the hedonic scale ratings. At the lower storage temperatures, the compressed samples were judged to have better appearance, more color and less aftertaste. At 38C storage temperature, the chili flavor level decreased more in the compressed products and they were found to be more stale. Of the two pretreatments, treatment with 5 percent glycerol appeared to yield a more acceptable product. It was interesting to note, however, that pretreatment with 2.5 percent glycerol made the beans substantially less hard and more mushy, although we do not know why this should be the case.

G. Beef Stew

1. Processing

As previously described, beef eyeround was cooked to an internal temperature of 77C, diced, then equilibrated in appropriate glycerol solutions. Additional constituents of beef stew include the following:

- Potatoes - Idaho Russet baking potatoes were peeled and then diced (0.95 x 0.95 x 0.95 cm). The diced potatoes were deep fried one minute and 30 seconds at 204C, then drained. The fried potatoes were then brought to a boil in water, drained, and freeze dried.

- Peas - Bird's Eye frozen peas were cooked in a 5% glycerol solution for 5 minutes, then allowed to cool in the solution approximately 2 hours. The peas were drained, then freeze dried.

- Carrots - Carrots were peeled, diced (0.95 x 0.95 x 0.95 cm), blanched for 7 minutes, then freeze dried.

- Seasoning - Crisco was mixed into seasoning until uniform.

Two variations of beef stew were prepared for storage:

- 10% glycerol in beef
- 5% glycerol in beef

Both variations were compressed in the same manner. Appropriate amounts of each ingredient were weighed into a bag then sealed. The bag containing the stew was placed in an oven at 82C for 10 minutes, then compressed to a 3.44×10^6 Pa load with a dwell time of 2 minutes.

The bars were placed in pouches, flushed with nitrogen, sealed, then placed in storage.

2. Objective Evaluation

The results of the objective evaluation conducted with compressed beef stew, initially and after storage, are found in Tables LIX and LX (APPENDIX). The data indicates that:

- Moisture Content: The moisture contents ranged from 2.0 percent to 6.0 percent. During storage no significant changes were noticed in moisture content.
- Compression: A preconditioning heat treatment and load of 3.45×10^6 Pa resulted in the formation of a satisfactory bar able to withstand normal handling. The density of the stew was increased from 0.18 gram/cc to 1.1 grams/cc. During storage, the density of compressed bars decreased to between 0.85 and 1.0.
- Rehydration: Each bar was rehydrated in 3 parts water to 1 part dinner. The bars rehydrated into an acceptable stew after approximately 20 minutes. The compressed bars rehydrated equally well after 90 days storage.
- Microbial Counts: The standard plate count of the compressed beef stew was below 1,000 and remained low during storage.

3. Sensory Evaluation

The results of the sensory panel evaluation by means of hedonic scale ratings are summarized in Table LXI (APPENDIX).

The data indicates that up to a storage time of 60 days, the control and the compressed samples were equally well liked at all storage temperatures. After 90 days storage, the control was preferred except at a storage temperature of -18C. The reason appears to be that the compressed samples deteriorated more in the last 30 days of storage than the control.

To elucidate the reasons for the hedonic scale ratings, a second series of sensory panel tests was conducted using the previously described modified profiling technique. The results of the tests are summarized in Table LXII (APPENDIX).

The profiles of the control and the compressed samples are relatively similar considering the experimental conditions used. At the shorter storage times, the differences appear to be in the texture of the potatoes and the meat. At 60 days storage, a stale note began to appear in the compressed samples, particularly at a storage temperature of 38C. After 90 days at the higher storage temperatures, the experimental compressed beef stew had a poorer appearance, was judged to be staler and tougher, and had more of an undesirable aftertaste and mushier vegetables. Neither of the two pretreatments used had a real advantage over the other, although the lower glycerol may have been marginally more effective.

II. Diced Beef

1. Processing

Beef eyeround was cooked to an internal temperature of 77C. When cool, the beef was diced (1.27 x 1.27 x 0.63 cm), removing excess fat and gristle. The beef was then soaked in a concentration of glycerol which resulted in predetermined glycerol levels when freeze dried.

Calculated on a dry weight basis, two variations of treated beef were compressed and stored at -18C, 28C, 38C.

- Beef was soaked in an equal part of 5% glycerol solution, excess solution was drained and beef was freeze dried after a 16 hour equilibration. Water was incorporated in the form of steam to a 4% level.

- Beef was soaked in an equal part of 10% glycerol solution, excess solution was drained and beef was freeze dried after 16 hour equilibration period. Water was incorporated in the beef in the form of steam to a 3% level.

Treated beef was separated into 20 gram samples and heated to 82C (10 minutes). The beef was finally compressed to a load of 6.9×10^6 Pa and a dwell time of 3 minutes.

The compressed beef bars were packed in pouches, flushed with nitrogen, sealed, then stored under appropriate conditions.

2. Objective Evaluation

The results of objective evaluations conducted with compressed diced beef, initially and after storage, are found in Table LXIII and LXIV (APPENDIX). The data indicates that:

- Moisture Content: The moisture content of compressed beef varied from 0.7 percent to 4.7 percent. During storage the moisture of the compressed bars decreased significantly.

- Compression: A load of 6.9×10^6 Pa was applied to the treated beef and the bar dwelled at this load for 3 minutes. The density of the beef was increased from 0.27 gram/cc to 1.20 gram/cc after compression. The beef bars expanded between 0 and 20 percent during storage.

- Rehydration: The beef bars separated readily when rehydrated in excess water at 85C. Beef was allowed to rehydrate 20 minutes before being objectively evaluated for water absorbtion qualities. The beef bars rehydrated to an acceptable moisture even after 90 days storage.

- Microbial Counts: Standard plate count ranged from 0 to 20,000 per gram. Counts remained low during storage.

3. Sensory Evaluation

The results of the sensory panel evaluation by means of hedonic scale ratings are summarized in Table LXV (APPENDIX).

The data indicates that the control and the compressed samples were about equally well liked at all storage times, and all storage temperatures, particularly when the pretreatment consisted of 5 percent glycerol and 5 percent moisture. An exception was 90 days storage at 28C, but the result is believed to be a spurious result in view of the other ratings. Also, no explanation is offered for the differences after 30 days storage at -18C.

To substantiate the hedonic scale ratings, a second series of sensory panel tests was conducted using the previously modified profiling technique. The results of the tests are summarized in Table LXVI (APPENDIX).

The profiles obtained are reasonably similar considering the experimental conditions used. They show clearly, particularly after 90 days storage at 38C that the pretreatment consisting of 5 percent glycerol and 5 percent moisture yielded a significantly better product than a pretreatment of 10 percent glycerol and 4 percent moisture. The latter led to a compressed product with poor appearance, low beef flavor, high off-flavor, a strong stale note, appreciable aftertaste, a tough texture, and poor overall quality. Generally, the texture of the compressed beef tended to be tougher than that of the control.

APPENDICES

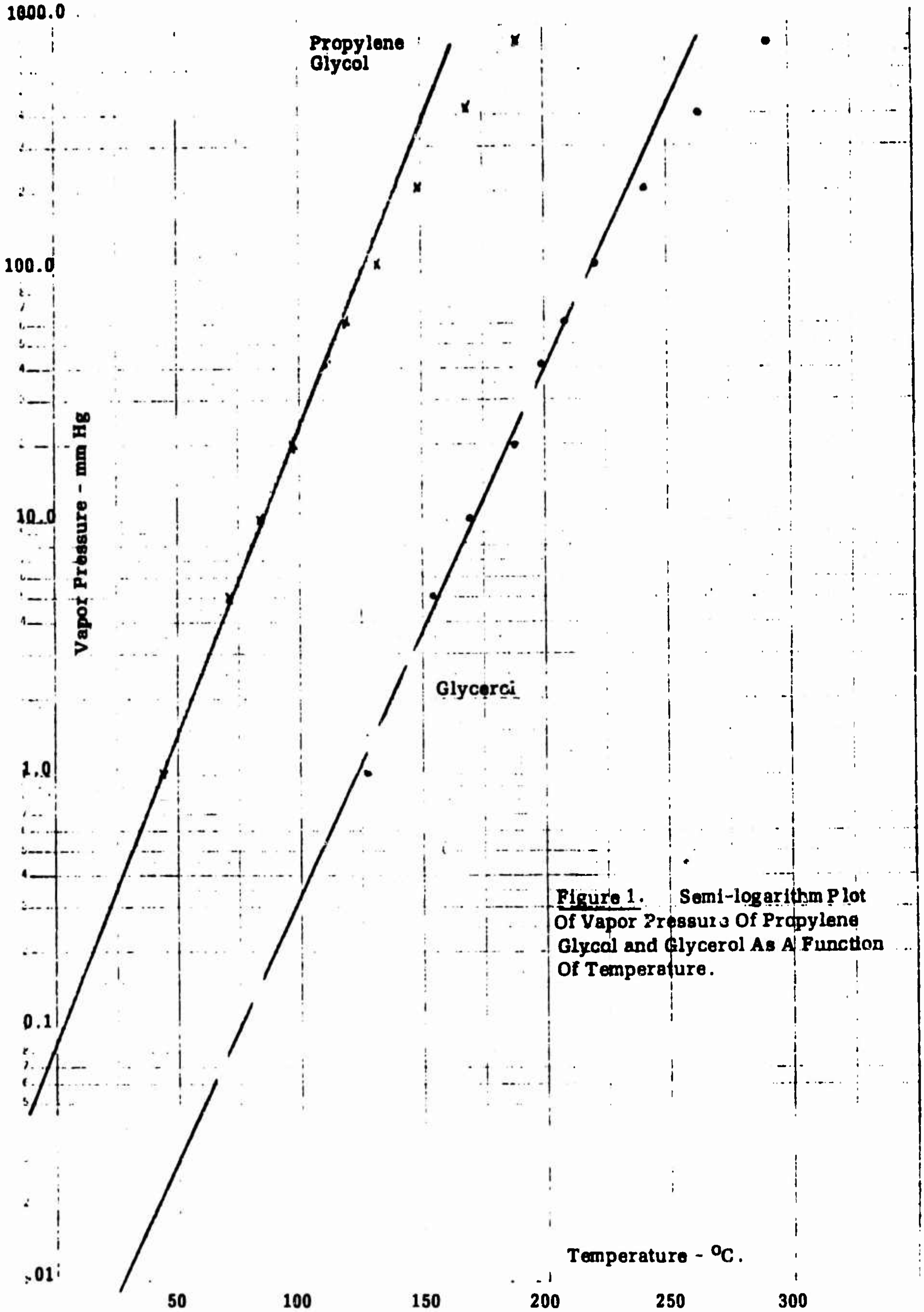
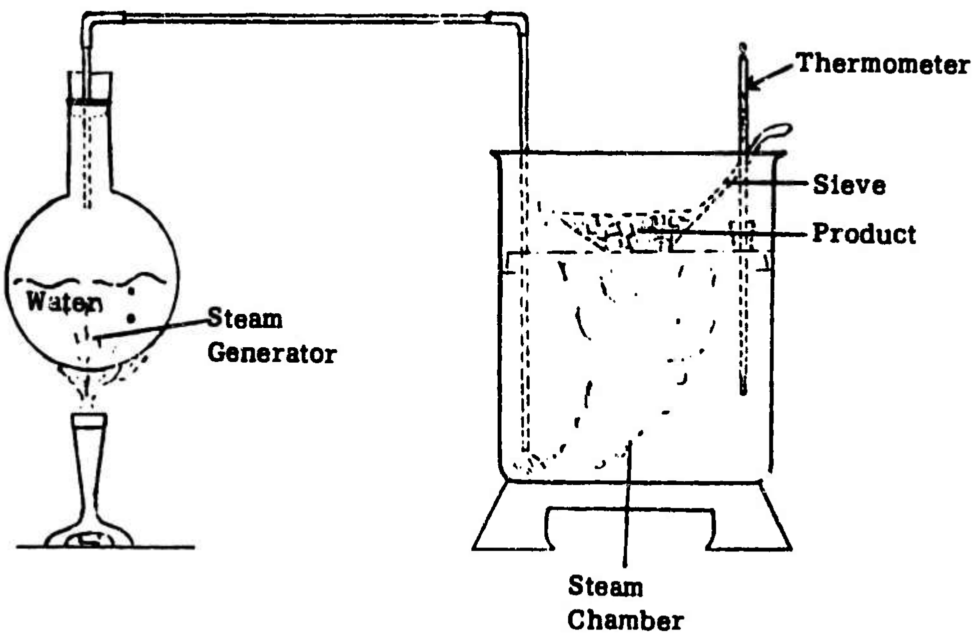


Figure 1. Semi-logarithm Plot Of Vapor Pressure Of Propylene Glycol and Glycerol As A Function Of Temperature.

Figure 2. Schematic of Steam Chamber



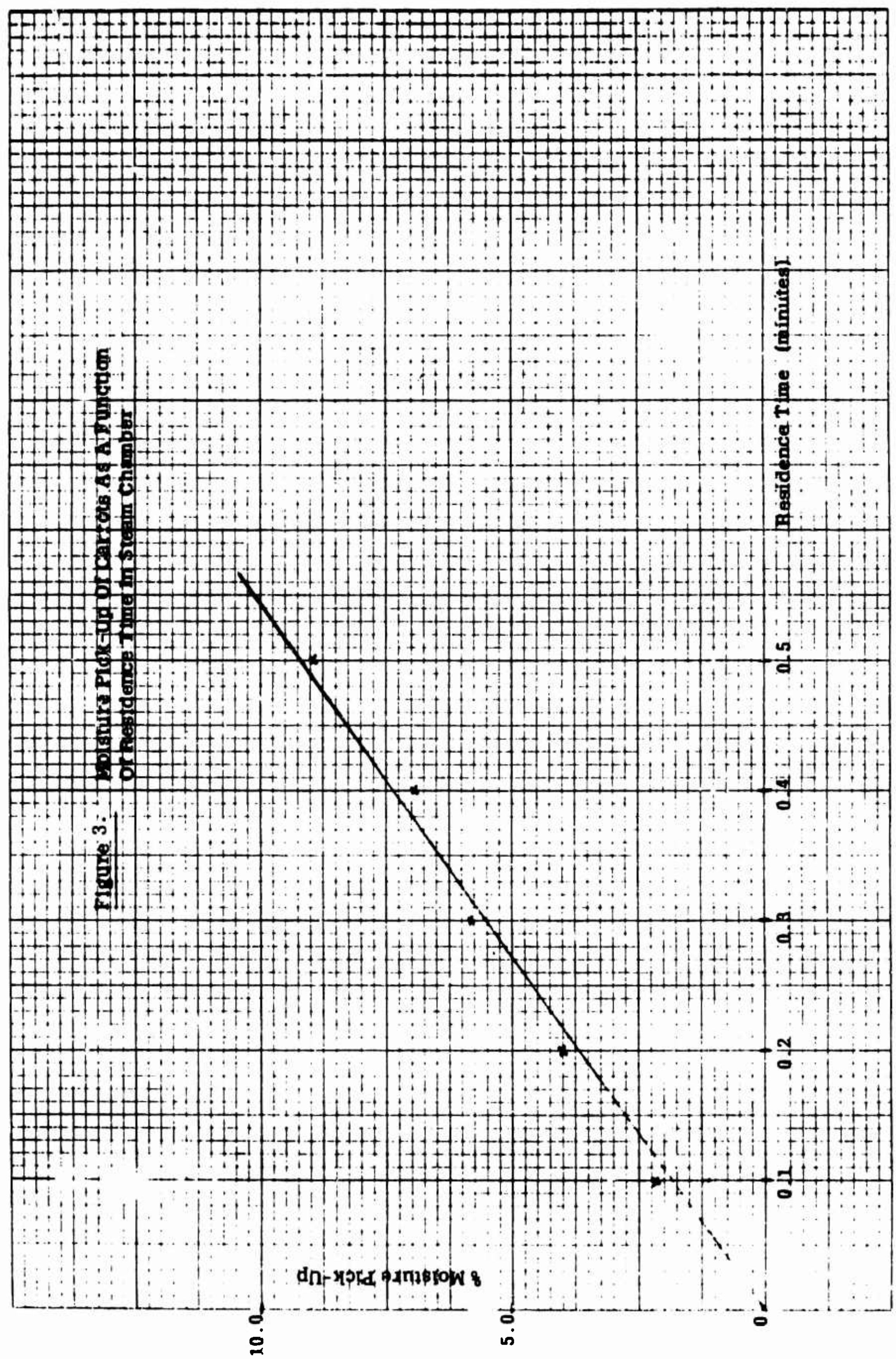


Figure 3: Moisture Pick-Up Of Carrots As A Function Of Residence Time In Steam Chamber

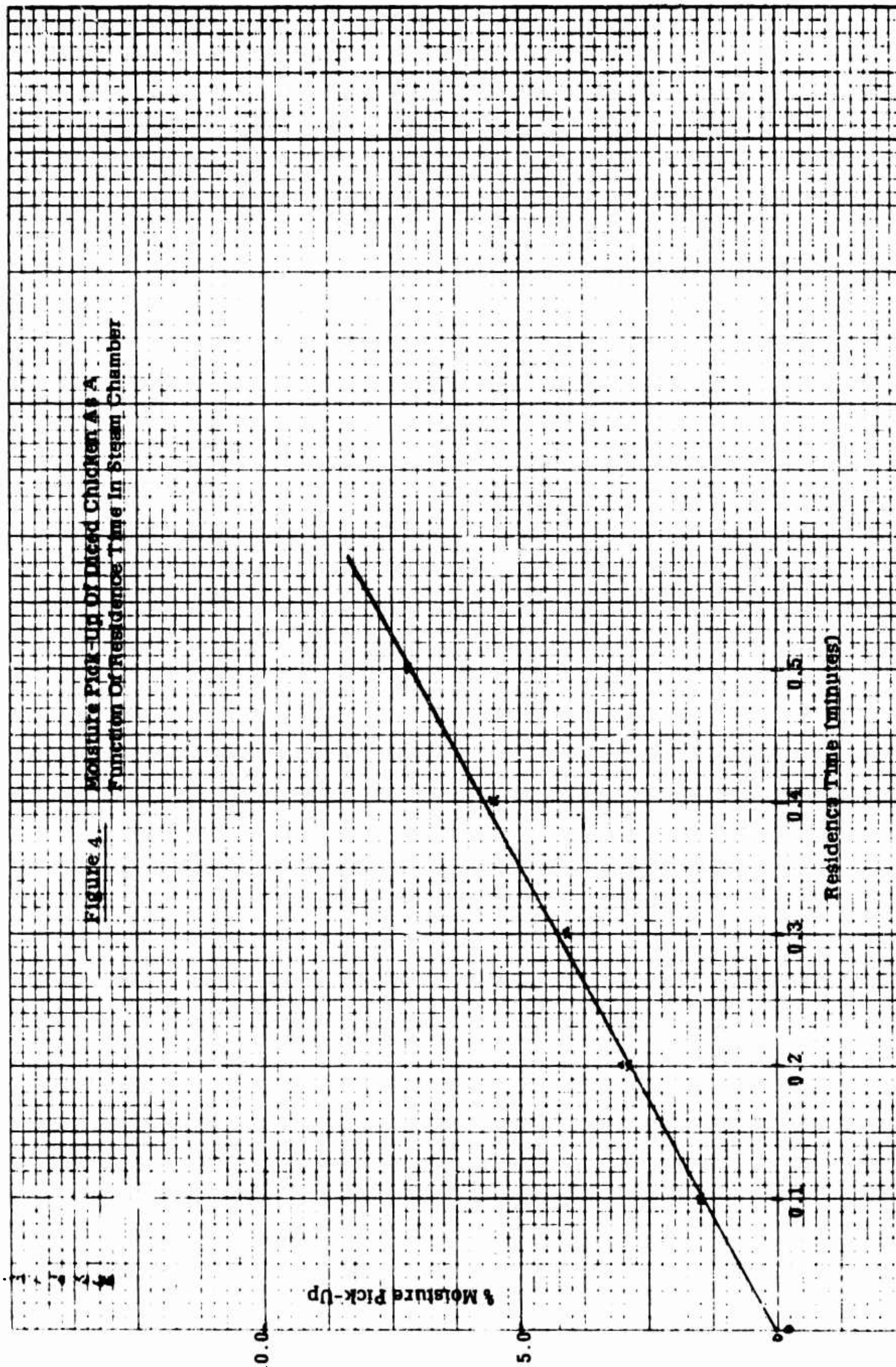


Figure 4. Moisture Pick-Up Of Diced Chicken As A Function Of Residence Time In Steam Chamber

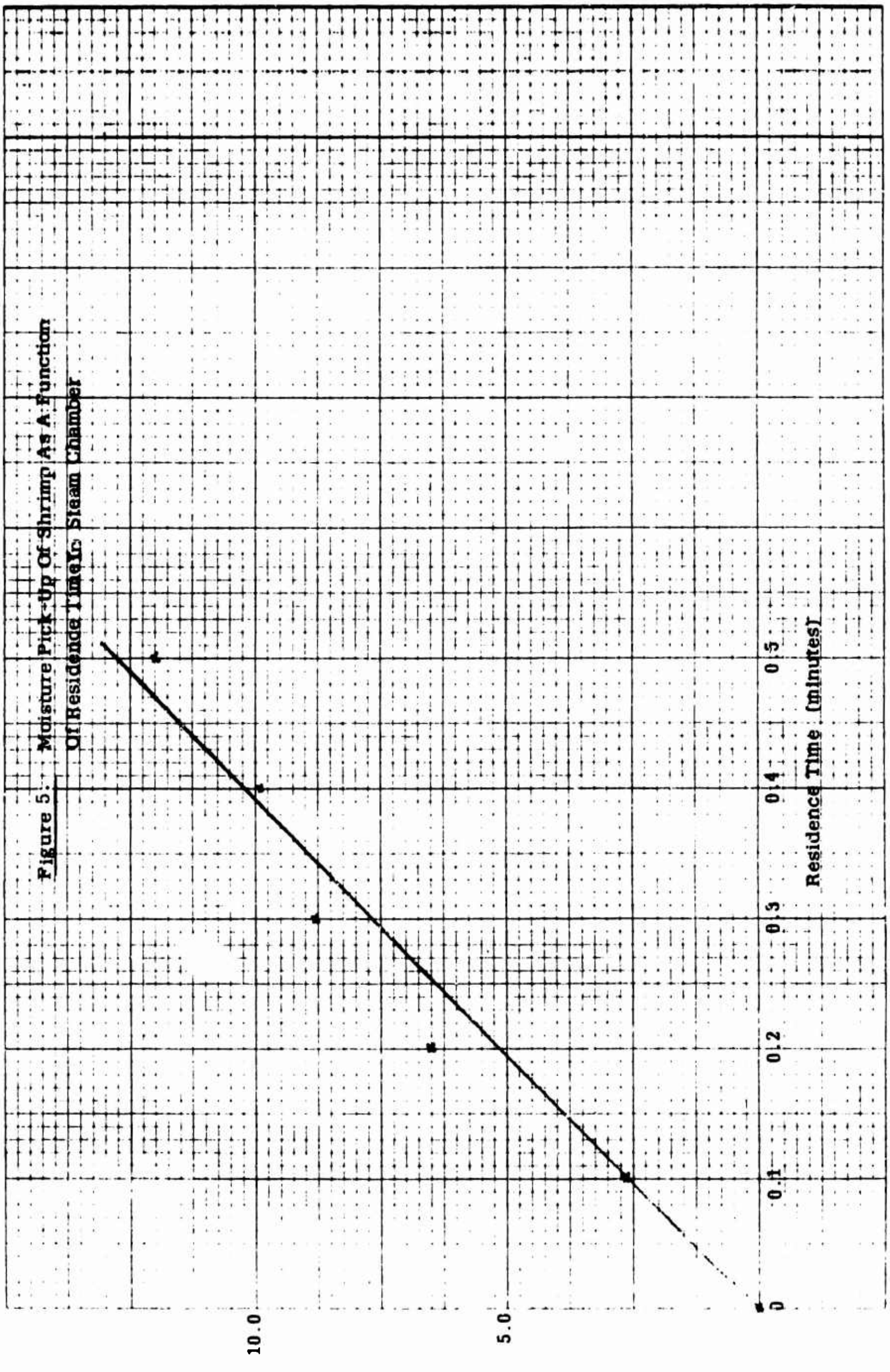


Figure 5: Moisture Pick-Up Of Shrimp As A Function Of Residence Time In Steam Chamber

TABLE I. EFFECT OF EQUILIBRATION TIME ~~AT 38C~~ UNDER VACUUM OF DICED CARROTS USING THE SPLIT STREAM PROCEDURE.

Storage Time (hrs.)	Moisture Content %	Condition of Wet Pieces: Before Compression	Condition of Wet Pieces: After Compression	Compressibility of dry portion	Rehydration Time (minutes): After Comp.	Rehydration Time (minutes): After 2nd freeze drying cycle	Comp. Ratio	Texture: Before Freeze Drying	Texture: After Freeze Drying	Color
2	5.15	very little shrinkage	completely pureed	partially compressible	11.6	9.0	8.0	close to control	slightly softer than control	no change
4	7.25	initial shrinkage	pureed	totally compressible	20.0	9.0	9.7	as control	as control	no change
6	9.50	noticeable shrinkage	broken but not pureed	totally compressible	15.0	18.0	10.2	as control	as control	no change
17	12.0	total shrinkage	no damage	totally compressible	4.5	over 20	8.8	as control	as control	no change
24	12.10	total shrinkage	no damage	totally compressible	10.0	16.0	8.1	as control	as control	no change

TABLE II

EFFECT OF EQUILIBRATION TIME ON PRODUCT CHARACTERISTICS USING SPLIT STREAM PROCEDURE
Diced Cooked Chicken

Time	Final Moisture Content %	Condition of Wet Pieces		Compress-ibility of Dry Portion	Rehydration Time (Minutes)	Texture	Color
		Before Compression	After Compression				
2	4.7	Little Shrinkage	Totally Broken	Partially Compressible	2	Broken Pieces	No Change
4	5.6	More Shrinkage	Negligible Damage	More Compressible	2	Broken Pieces	No Change
6	6.5	Still Shrinking	No Damage	Totally Compressible	1	Comparable to Control	No Change
17	7.3	Maximum Shrinking	No mechanical Damage	As Above	1	As Above	No Change
24	8.3	Maximum Shrinking	No mechanical Damage	As Above	1	As Above	No Change

TABLE III

EFFECT OF VARIOUS PLASTICIZING AGENTS ON COMPRESSIBILITY AND REHYDRATION OF FREEZE DRIED DICED CARROTS. EQUILIBRATION FOR 12 HOURS AT 50C.

Plasticizing Agent	Concentration Level on Dry Weight Basis (%)	Remarks
Corn Oil (Mazola)	5 10 15	Reconstituted, compressed carrots showed excessive disintegration at all levels. Penetration of oil to the product was very slight as observed by visual inspection of various sections. Rehydration time for 15% samples was 10 minutes
Propylene Glycol	5	Some disintegration observed.
	10	Less disintegration.
	15	Least disintegration. Rehydration time - 1 minute. Closest to control non-compressed samples.
Glycerol	5 10 15	Reconstituted compressed carrots showed excessive breakage at all concentration levels. Penetration into the product was very slight. Samples with 15% glycerol required about 7 minutes for rehydration.

TABLE IV. EFFECT OF VARIOUS LEVELS OF PLASTICIZING AGENTS ON REHYDRATION CHARACTERISTICS OF COMPRESSED DICED CARROTS. EQUILIBRATION FOR 3 HOURS AT 50C.

Plasticizing Agent	Conc. Level % Weight	Rehydration Time (min.)	Discoloration* of sample compared to control	Texture* compared to control	Taste of* rehydrated samples compared to control	% Pulverized **	% expansion after 24 hours at room temp.
Propylene Glycol	5.0	0.7	-3	-3	0	3.5	23.2
	7.5	0.57	-2	-1	0	1.1	52.7
	10.0	0.6	-2	-1	-1	0.3	44.3
	15.0	0.9	-1	-1	-2	0.07	64.4
75% Propylene Glycol	10.0	1.5	-3	-2	-2	1.3	35.4
25% Glycerol	15.0	1.2	-3	-2	-2	2.4	21.6

** Comparative Data Only.

* Discoloration, texture, and taste were determined by four people on an unstructured panel basis. Color was determined visually compared to a freeze dried, uncompressed rehydrated sample. Texture was determined by hand and mouthfeel of the product.

The following scales were used:

Color
- -4 = very much darker
- -3 = much darker
- -2 = definitely darker
- -1 = slightly darker
- 0 = Control

Texture
- -4 = very much softer
- -3 = much softer
- -2 = definitely softer
- -1 = slightly softer
- 0 = Control

TABLE V

EFFECT OF EQUILIBRATION TIME AT ROOM TEMPERATURE. PROPYLENE GLYCOL 7.5% APPLIED TO DICED CARROTS.

Equilibration Time (hrs.)	Initial Packing Density	Final Packing Density	Compression Ratio	% Expansion After 24 Hours	Rehydration Time	Taste	Texture	Discoloration
0	0.089	0.443	4.95	21.1	0.86	0	-3	-0
1	0.090	0.445	4.92	25.6	1.05	0	-3	+0
2	0.097	0.465	4.80	22.9	1.13	0	-3	0
4	0.095	0.464	4.86	32.9	1.32	0	-2	0
6	0.096	0.485	5.05	15.7	1.41	0	-1-0	0
24	0.093	0.476	5.14	32.5	0.82	0	-1-0	0

Scales, See Table IV

TABLE VI

EFFECT OF 7.5% OF PROPYLENE GLYCOL WATER MIXTURE ON COMPRESSIBILITY AND REHYDRATION CHARACTERISTICS OF FREEZE DRIED CARROTS.

Plasticizer Agent									
Propylene Glycol %	Water %	Method	Density before Compression	Density after Compression	(Min.) Rehydration Time	Comp. Ratio	Texture	Taste	% Pulverized
90	10	Compressed immediately after spraying	0.101	0.490	1.37	4.84	-2	0	-
75	25		0.101	0.519	2.15	5.11	-2	0	-
50	50		0.100	0.537	1.45	5.35	-1	0	-
90	10	30 Minutes equilibration at oven 50C compressed at room temperature	0.101	0.498	0.94	4.94	-1	0	-
75	25		0.101	0.512	1.45	5.05	-1	0	-
50	50		0.102	0.578	0.75	5.69	-1	0	-
90	10	1 Hour equilibration at 50C compressed at room temperature	-	-	0.5	-	-1	-	6.9
75	25		-	-	0.47	-	-1-0	-	2.4
50	50		-	-	0.31	-	-1-0	-	0.96
		Scales. See Table IV							

TABLE VII. EFFECT OF EQUILIBRATION CONDITIONS ON COMPRESSIBILITY AND REHYDRATION CHARACTERISTICS OF DICED CARROTS.

Equilibration Method		Plasticizer: propylene glycol %	Plasticizer: water %	total plasticizer level %	% moisture prior to compression	rehyd. time (min.)	texture *	% Pulverized	Density: after compression	Density: before compression	Comp. Ratio	Taste
Compressed immediately after spraying	C_1	75	25	7.5	7.25	3.[illegible]0	-1	0.19	0.620	0.111	5.92	0
	A_1	50	50	7.5	6.20	1.50	-1	0.23	0.585	0.099	5.88	0
	D_1	75	25	10.0	8.85	6.06	0	0.09	0.657	0.120	6.62	0
	B_1	50	50	10.0	6.36	2.47	0	0.03	0.792	0.109	5.70	0
	E_1	75	25	12.5	9.57	10.72	-1	0.18	0.853	0.114	7.50	0
Compressed warm, after 15 minutes storage at 50C	C_2	75	25	7.5	6.71	0.71	0	0.02	0.623	0.112	5.36	0
	A_2	50	50	7.5	5.51	0.83	0	0.01	0.557	0.108	5.14	0
	D_2	75	25	10.0	7.42	1.81	0	0.02	0.598	0.120	6.43	0
	B_2	50	50	10.0	6.25	1.32	0	0.04	0.770	0.104	6.00	0
	E_2	75	25	12.5	9.17	6.71	-1	0.15	0.819	0.124	6.62	0
Compressed after 2 hours in vacuum at room temp.	C_3	75	25	7.5	4.64	0.36	-3	3.82	0.637	0.102	6.34	0
	A_3	50	50	7.5	5.95	0.67	0	0.07	0.553	0.106	5.20	0
	D_3	75	25	10.0	6.39	0.45	-2	1.24	0.644	0.117	6.72	0
	B_3	50	50	10.0	6.35	1.14	0	0.03	0.784	0.108	5.92	0
	E_3	75	25	12.5	8.65	1.02	-1	0.26	0.795	0.116	6.87	0
Freeze dried Not Compressed												0

* See Table IV for scale

TABLE VIII

THE EVALUATION OF VARIOUS BINDERS TO REDUCE EXPANSION OF COMPRESSED CARROTS

Code	Treatment	Plasticizing Agent	% Plasticizer on Dry Weight Basis	Binders	% Binder on Dry Weight Basis
100	Compressed at 6.9×10^6 Pa immediately after steaming with zero dwell time	50% P.G.*, 50% Steam	7.5	0	0
101		50% P.G., 50% Steam	7.5	90% Starch, 10% CMC	5
102		50% P.G., 50% Steam	7.5	90% Lactose, 10% CMC	5
103	As Above	50% P.G., 50% Steam	10.0	0	0
104		50% P.G., 50% Steam	10.0	90% Starch, 10% CMC	5
105		50% P.G., 50% Steam	10.0	90% Lactose, 10% CMC	5
200	As Above	75% P.G., 25% Steam	7.5	0	0
201		75% P.G., 25% Steam	7.5	90% Starch, 10% CMC	5
202		75% P.G., 25% Steam	7.5	90% Lactose, 10% CMC	5
203	As Above	75% P.G., 25% Steam	10.0	0	0
204		75% P.G., 25% Steam	10.0	90% Starch, 10% CMC	5
205		75% P.G., 25% Steam	10.0	90% Lactose, 10% CMC	5
300	Compressed immediately at 6.9×10^6 Pa with zero dwell time	100% P.G.	7.5	0	0
301		100% P.G.	7.5	Gelatin dissolved in P.G.	2
302	As Above	100% P.G.	10.0	0	0
303		100% P.G.	10.0	2% Gelatin dissolved in P.G.	2
304	Compressed at 6.9×10^6 Pa immediately after steaming with zero dwell time	75% P.G. containing 2% gelatin, 25% Steam	10.0	90% Starch, 10% CMC	7.5
305		As Above	10.0	90% Lactose, 10% CMC	7.5

TABLE VIII (Cont'd)

Code	Treatment	Plasticizing Agent	% Plasticizer on Dry Weight Basis	Binders	% Binder on Dry Weight Basis
400	Compressed at 6.9 x 106 Pa with 1 hour dwell time	50% P.G. containing 2% Gelatin, 50% Steam	10.0	90% Starch, 10% CMC	7.5
401		As Above	10.0	90% Lactose, 10% CMC	7.5
402		75% P.G. containing 2% Gelatin, 25% Steam	10.0	90% Starch, 10% CMC	7.5
403		As Above	10.0	90% Lactose, 10% CMC	7.5
404	Compressed at 6.9×10^6 Pa with no steaming and zero dwell time	96% P.G., 4% Gelatin	10.0	-	-
405		94% P.G., 6% Gelatin	10.0	-	-

* Propylene Glycol

TABLE IX

EFFECT OF VARIOUS PLASTICIZING AGENTS/ BINDERS COMBINATIONS ON PRODUCT PERFORMANCE

Code	% Expansion after 24 hours at room temperature	Bar appearance* before dehydration	Rehydration Time (Minutes)	Texture and* appearance of reconstituted product	% Moisture
100	57.1	-2	6.5	-1 to -2	5.2
101	78.8	-4	6.2	-1 to -2	-
102	60.4	-2	11.0	-1 to -2	-
103	62.5	-2	10.0	0	-
104	78.8	-4	9.5	0	-
105	72.9	-4	6.0	0	-
200	38.0	-1	4.5	-2 to -3	6.7
201	42.8	-2	10.0	-2	-
202	50.8	-2	3.7	-2	-
203	44.2	-1	4.0	-1	-
204	53.3	-2	9.2	-1	-
205	50.0	-3	3.1	-1	-
300	14.8	0	4.2	-4	5.6
301	16.7	0	9.2	-4	-
302	8.8	0	5.6	-4	-
303	7.6	0	6.0	-4	-
304	36.6	-1	18.0	-2	-
305	19.7	-1	12.0	-3	-
400	36.9	-1	60.0	0 to -1	-
401	44.1	-1	45.0	0 to -1	-
402	32.0	-1	60.0	0 to -1	-
403	38.0	-1	45.0	0 to -1	-
404	6.7	0	60.0	-4	-
405	8.0	0	60.0	-4	

* See Table IV for scale used

TABLE X

EFFECT OF COMPRESSION PRESSURE AND DWELL TIME ON BAR CHARACTERISTICS

Pressure	Dwell Time (minutes)	Code	% Expansion	Bar Condition Before Compression*	Rehydration Time (minutes)	Texture
6.9×10^6 Pa	15	100	42.9	-1	18.0	-1
		101	37.5	-1	40.0	-2
		102	42.0	-1	19.0	-1
		203	36.7	-1	23.0	-1
		204	32.7	-1	45.0	-2 to -3
6.9×10^6 Pa	30	100	26.7	-1	20.0	0 to -1
		101	23.9	-1	58.0	-1 to -2
		102	28.0	-1	31.0	0 to -1
		203	22.9	-1	35.0	-2 to -3
		204	18.0	-1	84.0	-1 to -2
6.9×10^6 Pa	45	100	30.6	-1	35.0	0 to -1
		101	23.9	-1	62.0	-1
		102	26.9	-1	55.0	0 to -1
		203	28.8	-1	47.0	-1
		204	21.7	-1	85.0	-1 to -2
13.8×10^6 Pa	15	100	29.1	-1	41.0	-2 to -3
		101	19.6	0	83.0	-2 to -3
		102	18.2	0	65.0	-2 to -3
		203	20.0	-1	65.0	-1
		204	19.3	0	85.0	-2 to -3
20.7×10^6 Pa	15	100	23.4	0	80.0	0 to -1
		101	18.5	0	95.0	-1
		102	17.0	0	80.0	0 to -1
		203	19.1	-1	85.0	0
		204	23.9	0	90.0	-1 to -2

* See Table I[illegible] for Scale

TABLE XI
THE EFFECT OF GLYCEROL AND GELATIN ON FABRICATED CHICKEN

Fabricated Chicken		Freeze-dried Compressed Chicken				
% Plasticizer Weight (wet basis)	Moisture Content %	Plasticizer Level	Moisture Content %	% Expansion	Rehydration Time (Min.)	Remarks
1. Glycerol 4%	61.7	Steam 5%	8.43	28.8	3.0	Better than control, best sample in texture.
2. Glycerol 6%	61.6	Steam 5%	8.10	32.4	6.0	Slightly better than control, but tougher than 1.
3. Glycerol 4% + 1.5% Gelatin	58.2	Steam 5%	-	21.1	2.8	Good.
4. Glycerol 5% + 1.5% Gelatin	57.5	Steam 5%	-	18.4	5.2	Good.
5. No plasticizer	-	Steam 5%	-	8.7	3.4	100% fragmented.
6. Commercial Chicken	-	Steam 5%	-	11.6	1.3	100% fragmented.
7. Glycerol 4%	-	-	5.70	-	1.0	Identical to 1.
8. Glycerol 6%	-	-	5.70	-	1.0	Good.

TABLE XII

EFFECT OF EQUILIBRATING CHICKEN IN GLYCEROL SOLUTIONS

Glycerol (grams)	Plasticizer	Rehydration time (min.)	Bar Appearance after Compression	Texture of Rehydrated Product
10.0	steam	8.0	-1 *	-1 to -2
10.0	none	1.0	broken	-4
15.0	steam	5.9	-1	0 to -1
15.0	none	1.0	broken	-4
20.0	steam	4.7	-1	0 to -1
20.0	none	1.0	broken	-4
25.0	steam	5.0	-1	0 to -1
25.0	none	1.0	broken	-4
0.0	steam	7.0	-1	0 to -1
0.0	none	1.0	broken	-4

* See Table IV for scale used.

TABLE XIII

EFFECT OF ALCOHOL/GLYCEROL SOLUTIONS ON DICED COOKED CHICKEN

Variables	Compression after 24 hours	Glycerol Added	Rehydration @ 85 C Time(mins.)	Rehydration @ 85 C Remarks
No Steam	soft bar	5.0%	1.5	badly broken, mushy
No Steam	bad	7.5%	1.5	"
No Steam	bad	10.0%	1.5	"
2.5% Steam	expanded	5.0%	4.0	50% good,
2.5% Steam	but	7.5%	3.0	but rest
2.5% Steam	acceptable	10.0%	3.0	broken
5.0% Steam	acceptable	5.0%	4.0	almost
5.0% Steam	"	7.5%	4.5	good as
5.0% Steam	"	10.0%	3.5	control

TABLE XIV

EFFECT OF PLASTICIZING AGENT ON REHYDRATION CHARACTERISTICS OF SHRIMP

Plasticizing Agent	CMC Level	Initial Density	Comp. Ratio	Final Density	Rehydration time (min.)	Texture	% Pulverized	Taste
Propylene Glycol	10.0	0.253	2.51	0.635	0.54	-1	1.88	0
	12.5	0.270	2.50	0.702	0.45	-1 -0	0.98	-1
Oil	10.0	0.273	2.35	0.642	0.69	-3	7.67	-1
	12.5	0.286	2.23	0.638	0.32	-3	15.93	-1
Glycerol and Ethanol	10.0	0.278	2.23	0.620	0.81	-1	2.30	-1
	12.5	0.278	2.23	0.620	0.93	-1	1.87	-1

Scales, See Table IV

TABLE XV

EFFECT OF LEVEL OF MIXTURE (WATER/PROPYLENE GLYCOL) AND EQUILIBRATION CONDITIONS ON COMPRESSIBILITY AND REHYDRATION OF SHRIMP

Equilibration Conditions		Plasticizing Mixture: Total Level %	P. G.*	H_2O %	% Moisture	Initial Density	Final Density	Comp. Ratio	% Pulverized	Rehydration Time (min)	Texture	Taste
Compressed immediately after	A_1	10	50	50	6.03	0.175	0.596	3.41	0.63	7.0	0	0
Spraying	B_1	10	75	25	5.20	0.169	0.586	3.46	6.68	10.0	-1	0
	C_1	12.5	75	25	5.44	0.174	0.645	3.60	3.23	15.0	-1	0
Compressed after 15 minutes	A_2	10.0	50	50	6.23	0.177	0.586	3.31	1.49	2.50	0	0
at 50C while warm	B_2	10.0	75	25	5.11	0.164	0.577	3.52	5.50	9.0	-1	0
	C_2	12.5	75	25	6.19	0.176	0.614	3.49	1.82	11.0	-1	0
Control		-	-	-	-	-	-	-	0.13	-	0	0

* Propylene Glycol

TABLE XVI

EFFECT OF EQUILIBRATION TIME AFTER STEAM APPLICATION ON PRODUCT PERFORMANCE (SHRIMP)

Equilibration Time (min.)	% Moisture	Rehydration Time (min.)	Remarks	Density before Compression	Density after Compression	Compression Ratio	% Expansion
0	3.10	0.75	Very good texture, and distinguishable from control.	0.180	0.551	3.1	15.6
15	3.13	0.95	Very good	0.184	0.580	3.2	21.7
30	3.47	1.00	Very good	0.187	0.562	3.0	17.3
60	3.86	1.00	Very good	0.176	0.550	3.1	20.1

TABLE XVII

PRELIMINARY FORMULATIONS OF MEAT BALLS

Ingredient	#100 Control (g)	#103 (g)	#105 (g)	#107 (g)	#108 (g)
Ground Chuck	79.0	79.0	79.0	79.0	79.0
Corn Meal	2.5	-	1.0	1.5	2.5
Gluten	-	1.5	1.5	-	-
Egg Albumin	-	-	-	1.0	-
Salt	1.0	1.0	1.0	1.0	1.0
Black Pepper	0.0625	0.0625	0.0625	0.0625	0.0625
Onion Powder	0.75	0.75	0.75	0.75	0.75
Shortening	3.2	3.2	3.2	3.2	-
Glycerol	-	-	-	-	7.0
H2O	13.5	13.5	13.5	13.5	13.5

TABLE XVIII

COMPRESSION - REHYDRATION DATA FOR MEAT BALL FORMULATIONS - (Table XVII)

Code	Initial Density	Compression Ratio	Rehydration Time (min.)	Taste	Texture
100	0.564	4.5	2.0	Comparable to Control	Flat, no recovery
103	0.527	4.9	1.25	Baked Flavor	Flat, no recovery
105	0.515	4.3	1.0	Baked Flavor	Flat, no recovery
107	0.511	4.9	2.25	Comparable to Control	Flat, no recovery
108	0.595	4.9	1.0	Sweet	Comparable to control
Control					Very good

TABLE XIX

FORMULATIONS OF MEAT BALLS
(In Grams)

Product	#600	#601	#602	#700	#701	#702	#800	#801	#802
Ground Chuck	79.0	79.0	79.0	79.0	79.0	79.0	79.0	79.0	79.0
Corn Meal	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Salt	1.0	1.5	2.0	1.0	2.5	2.0	1.0	1.5	2.0
Black Pepper	0.0625	0.0625	0.0625	0.0625	0.0625	0.0625	0.0625	0.0625	0.0625
Onion Powder	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Water	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
Glycerine	3.2	3.2	3.2	5.0	5.0	5.0	7.0	7.0	7.0

TABLE XX

EFFECT OF GLYCEROL LEVEL IN MEAT BALL FORMULATIONS

Code	% Moisture	Density Before Compression	Density After Compression	Compression Ratio	% Expansion	Rehydration Time (minutes)	Texture
600	-	0.220	0.90	4.1	13.3	1.4	Some flat, slightly broken
601	-	0.263	1.024	3.9	25.3	1.3	"
602	-	0.267	1.024	3.8	19.8	1.5	"
700	-	0.267	1.100	4.1	32.5	1.4	Slightly broken
701	-	0.253	0.965	3.8	27.1	1.2	"
702	-	0.282	1.410	4.0	25.5	1.2	"
800	3.51	0.263	1.251	4.8	36.2	1.3	Comparable to control
801	3.95	0.265	1.160	4.4	25.8	1.8	"
802	3.38	0.298	1.178	3.9	21.1	2.0	"

TABLE XXI

BASIC FORMULATION FOR CHICKEN AND RICE

Ingredients	%
Chicken, cooked and diced	38.5
Uncle Ben's Converted Rice (uncooked)	9.6
Soup and Gravy Base	2.5
Salt	-
Water	41.5
Vegetable Oil	4.8
Pimentos	2.1

Procedure

All ingredients, except rice and chicken, were heated to 82C. The rice was then added and the solution heated to a boil, removed from heat and allowed to stand for 5 minutes. The diced precooked chicken was then added with gentle stirring and brought to a temperature of 82C.

TABLE XXII

BASIC FORMULATION FOR CHICKEN GRAVY MIX AND SPICE MIX

Chicken Gravy Mix

Ingredients	%
Salt	30.0
Chicken Fat	5.0
Dried Chicken Solids	1.45
Mono Sodium Glutamate	10.0
Onion Powder	2.0
Sugar	10.0
Starch (Instant Cleargel)	10.0
Hydrogenated Vegetable Oil	10.0
Chicken (Corral)	2.0
Spice Mix #200	0.5
Magge HPP Type 245	5.0
Milk Solids	14.0
Garlic	0.05
	100.00

Spice Mix #200

	Grams
Ground Black Pepper	1.4
Ground Celery	2.5
Ground Rosemary	1.1
Ground Turmeric	0.8
Ground Nutmeg	0.2
	6.0

TABLE XXIII

BASIC FORMULATION FOR CHILI CON CARNE

Ingredients (wet)	%
Beef - Ground Sirloin	35.0
Red Kidney Beans	35.0
* Seasoning Mix	3.0
Tomato Paste	10.0
Water	17.0

Procedure

Seasoning mix and water were mixed and heated to 82C. Ground beef was then added and stirred until meat is cooked.

* Tomato paste was added and mixture brought to 82C, followed by the addition of cooked beans and simmering for 15 minutes.

TABLE XXIV

BASIC COMPOSITION OF SEASONING MIX AND SOUP AND GRAVY BASE

Seasoning Mix

Ingredients	%
Soup and Gravy Base	44.0
Chili Powder	34.0
Salt	18.0
Garlic Powder	0.3
Onion Powder	3.2
Monosodium Glutamate	0.2
Ground Red Pepper	0.3
	100.0

Soup and Gravy Base

Hydrolyzed Protein Maggi 245 Powder	40.0
Beef Extract (Corral)	15.0
Monosodium Glutamate	18.0
Onion Powder	8.0
Autolyzed Yeast	10.0
Crisco	3.0
Sugar	2.0
Celery	0.10
(Warner Jenkinson #5166)	
Caramel Coloring	0.03
(PFW) Imitation Mushroom	0.10
(Basic) Powdered Toasted Onion	4.0
	100.0

TABLE XXV

BASIC FORMULATION OF BEEF STEW

Ingredients (wet)	%
Beef, cooked and diced (1.25 x 1.25 x 0.62 cm)	38.8
Potatoes, raw, diced	16.0
Peas (Frozen)	3.3
Carrots, raw, diced	4.6
Vegetable Oil	2.0
Seasoning Mix	3.3
Water	32.0

TABLE XXVI

BASIC FORMULATION OF SEASONING MIX

Ingredients	%
Soup and Gravy Base (Beef) (See Table XVI)	50.0
Starch (instant Gel)	36.0
Salt	7.0
Onion Powder	2.0
White Pepper (Ground)	0.9
Dehydration Onions (diced)	4.1

TABLE XXVII

DICED CHICKEN EVALUATION

Treatment *	Appearance	Flavor Level	Salty	Off-Flavor	Old, Stale	Rancid	Aftertaste	Rubbery, Tough	Completely Rehydrated Chicken	Overall Quality	Sweet
21	5.7	4.3	2.1	0.6	2.0	0.3	0.6	4.3	6.4	4.6	0.3
43	5.4	3.7	2.1	1.8	1.8	0.6	1.1	5.2	6.1	3.6	0.5
65	5.5	4.3	2.8	2.0	2.1	0.6	1.2	4.5	5.9	4.1	0.7
87	4.6	4.3	1.7	1.1	1.7	0.7	0.7	4.7	6.7	4.3	0.6
90	5.7	3.9	1.8	1.7	4.4	0.2	1.2	4.2	6.6	4.4	0.8

* #21 = Control
#43 = Compressed, 10% Glycerol, 4% Moisture Added
#65 = Compressed, 10% Glycerol, 5% Moisture Added
#87 = Compressed, 15% Glycerol, 4% Steam Added
#90 = Compressed, 15% Glycerol, 5% Steam Added

Number of Judgements = 10

High scores desirable

TABLE XXVIII

MEATBALL FORMULATION

Ingredient	Control (g)	Modification I (g)	Modification II (g)
Ground Sirloin	79.0	79.0	79.0
Corn Meal	2.5	2.5	2.5
Salt	1.0	1.0	1.0
Black Pepper	0.0625	0.0625	0.0625
Onion Powder	0.75	0.75	0.75
Water	13.5	13.5	13.5
Glycerol	-	5.0	7.0
Shortening-Crisco	3.2	-	-
Tween 60	-	0.04	0.04

TABLE XXIX

MEATBALL EVALUATION

Sample	Overall Appearance	Flavor Level	Sweet	Aftertaste	Old, Stale	Mealy	Rubbery	Completely Rehydrated
12	5.6	4.6	2.1	1.7	1.8	3.4	1.9	7.3
34	4.9	3.5	1.9	1.2	2.2	3.7	3.4	7.0
56	5.5	4.8	3.6	2.3	2.0	3.7	2.3	6.8
78	6.0	4.4	4.1	2.2	2.1	3.3	2.3	6.2

#12 = Control

#34 = Modification I, 4% Steam, Compressed, 5 grams Glycerol, equilibrated for 17 hours.

#56 = Modification I, 6% Steam, Compressed, 7.5 grams glycerol, No equilibration.

#78 = Modification II, 6% Steam, Compressed, 7.0 grams glycerol, No equilibration.

Number of Judgements = 10 High scores are desirable

TABLE XXX

CHICKEN AND RICE EVALUATION

Treatment	Overall Appearance	Toughness of Chicken	Comp. Rehyd. Chicken	Chicken Flavor Level	Distinct Rice Grain	Comp. Rehyd. Rice	General Spice Level	Flavor Balance	Off-Flavor	Old, Stale	Aftertaste
18	6.5	2.5	5.7	4.9	6.5	6.4	5.2	5.8	0.6	0.8	0.4
23	3.2	3.8	3.8	3.2	2.7	5.1	3.9	3.7	2.5	2.3	1.4
45	4.5	4.0	4.1	4.1	4.1	5.8	4.3	5.0	1.9	2.1	1.1
71	3.0	4.3	3.5	3.1	2.8	5.1	4.2	3.8	3.1	2.3	1.7

#18 = Control

#23 = 7% Glycerol, 4% Moisture, Compressed

#45 = 5% Glycerol, 5% Moisture, Compressed

#71 = 7% Glycerol, 5% Moisture, Compressed

Number of Judgements = 10 High scores are desirable

TABLE XXXI

CHICKEN AND RICE FORMULATIONS AND TREATMENTS

Ingredient	#200 Control %	#201 %	#202 %
Freeze-Dried Chicken	40.5	37.6	38.4
Freeze-Dried Rice	30.5	28.3	29.0
Soup & Gravy Base	7.8	7.2	7.4
Hydrogenated Shortening	14.9	13.9	14.2
Pimentos	6.3	5.8	5.9
Tween 60%	---	0.1	0.1
Glycerol	---	7.1	4.8
Moisture Added	---	5.0	5.0

TABLE XXXII

CHILI CON CARNE EVALUATION

Sample	Overall Appearance	Overall Color	Chili Flavor Level (heat)	Old, Stale	Aftertaste	Hardness of Beans	Mushiness of Beans	Comp. Rehyd.
#15	3.9	4.7	3.5	2.0	2.3	2.4	4.4	4.5
#37	4.5	5.4	5.1	1.0	2.6	3.6	2.3	5.9
#54	3.6	4.3	3.4	2.1	2.6	3.4	3.2	4.2
#89	3.3	4.0	3.1	2.5	2.9	2.4	4.2	4.6

#15 = 5% Glycerol, 4.0% Moisture

#37 = Control

#54 = 2.5% Glycerol, 4.0% Moisture

#89 = 2.5% Glycerol, 2.0% Moisture

Number of Judgements = 10

High scores are desirable

TABLE XXXIII

CHILI CON CARNE FORMULATIONS AND TREATMENTS

Ingredient	Control #100 %	#101 %	#102 %
Ground Sirloin	37.9	35.9	36.9
Kidney Beans	45.8	43.5	44.6
Seasoning Mix	7.9	7.5	7.7
Tomato Paste	8.4	8.0	8.2
Tween 60	----	0.1	0.1
Glycerol	----	5.0	2.5
Moisture Added	----	4.0	4.0

TABLE XXXIV

BEEF STEW FORMULATIONS

Ingredients	%	Variable I		Variable II	
		% Steam	% Glycerol	% Steam	% Glycerol
Freeze Dried Beef Dice	59.6	5	5	2	10
Freeze Dried Potato Dice	12.9	15	-	15	-
Freeze Dried Peas	3.0	5	5	5	5
Freeze Dried Carrot Dice	2.8	5	-	5	-
Seasoning Mix	13.4	-	-	-	-
Hydrogenated Shortening	8.1	-	-	-	-
Tween					

All heated in 82C and compressed. Beef in Variable II has 1% salt and 0.15% Tween 60 added, and beef in Variable I has 0.15% Tween 60 only.

TABLE XXXV

OBJECTIVE MEASUREMENTS OF BLANCHED DEHYDRATED CARROTS (ZERO STORAGE TIME)

Treatment / Parameter	3.75% Propylene Glycol - 3.75% Steam #41	7.5% Propylene Glycol - 2.5% Steam #23	5% Water #95	10% Propylene Glycol #87
Moisture content after compression (%)	5.72	5.22	6.40	6.39
Moisture content after rehydration (%)	85.60	86.20	85.10	89.00
Density before compression	0.1	0.1	0.1	0.1
Density after compression	1.0	1.0	1.0	1.0
Rehydration time (minutes)	7.0	8.3	6.0	5.0
Color of bar:				
1. Lightness (L)	64.4	66.5	69.0	63.3
2. Redness (a)	20.1	19.9	17.3	21.1
3. Yellowness (b)	31.3	30.2	33.4	26.9
Microbial count (microorganisms/gram)	950.0	1200.0	900.0	1000.0

TABLE XXXVI

OBJECTIVE EVALUATION OF STORED CARROTS

Storage time days	Sample Storage Temperature / Observation	A -18	A 28	A 38	B -18	B 28	B 38	C -18	C 28	C 38
30	Moisture %	4.8	4.8	4.7	5.7	5.7	6.2	3.6	3.0	3.7
	Density	0.63	0.64	0.59	0.60	0.61	0.68	-	-	-
	Expansion	52.9	55.1	63.5	54.2	41.5	53.6	-	-	-
	Rehyd. Time, Minutes	9.6	8.2	7.2	8.0	8.5	6.4	7.0	7.0	7.0
	Rehyd. Moisture %	88.5	88.2	86.3	86.6	88.5	86.4	85.9	85.9	86.4
	Microbial Count	<100	<100	<100	<100	<100	<100	<100	<100	<100
60	Moisture %	4.9	5.0	4.8	5.5	5.3	5.7	3.2	3.7	3.4
	Density	0.63	0.64	0.59	0.59	0.60	0.67	-	-	-
	Expansion %	52.9	55.1	63.4	57.0	43.9	56.3	-	-	-
	Rehyd. Time, Minutes	6.8	8.0	11.5	6.5	8.2	7.9	7.0	7.0	7.0
	Rehyd. Moisture %	86.6	86.3	84.9	83.7	85.8	[illegible].3	85.0	84.6	82.1
	Microbial Count	<100	<100	<100	<100	<100	<100	<100	<100	<100
90	Moisture %	4.2	4.2	4.3	5.4	5.3	5.6	3.8	3.1	3.5
	Density	0.67	0.67	0.68	0.67	0.67	0.68	-	-	-
	Expansion %	52.9	55.1	63.5	57.0	43.9	56.2	-	-	-
	Rehyd. Time, Minutes	10.6	7.3	10.0	9.2	12.5	10.3	8.0	8.0	8.0
	Rehyd. Moisture %	86.8	85.8	83.8	85.3	85.0	81.6	85.5	84.5	86.0
	Microbial Count	250	<100	100	<100	<100	<100	150	<100	200

Pre-treatment

A 7.5% propylene glycol, 2.5% steam; B 3.75% propylene glycol, 3.75% steam; C control

TABLE XXXVII

DICED CARROTS

SUMMARY OF SKEWED HEDONIC SCALE RATINGS

Treatment	Temperature C	Time of Storage (Days)			
		0	30	60	90
CONTROL	-18	5.2	3.8	4.3	5.5
	28	5.2	4.6	3.9	3.3
	38	5.2	4.4	3.9	3.0
3.75% Propylene Glycol 3.75% Steam	-18	5.9	4.9	4.9	5.7
	28	5.9	2.6	2.8	4.6
	38	5.9	3.2	3.0	1.3
7.5% Propylene Glycol 2.5% Steam	-18	4.4	3.8	4.4	5.7
	28	4.4	4.8	3.6	4.6
	38	4.4	1.6	1.2	1.3

TABLE XXXVIII
DICED CARROTS - SUMMARY OF PROFILE RATINGS

Pre-treatment: A = Control; B = 3.75% propylene glycol, 3.75% steam; C = 7.5% propylene glycol, 2.5% steam

Storage time, days	Sample Storage Temperature / Attributes	A -18C	A 28C	A 38C	B -18C	B 28C	B 38C	C -18C	C 28C	C 38C
0	Appearance		6.4			6.4			6.6	
	Flavor Level		4.8			5.2			4.4	
	Cooked Carrot Flavor		3.9			4.6			4.2	
	Sweet		3.9			4.1			3.6	
	Off-flavor		0.7			1.0			1.9	
	Old, Stale		0.8			1.0			1.7	
	Aftertaste		1.3			1.1			1.8	
	Tough		1.6			1.1			2.6	
	Mushy, Soggy		2.4			3.1			2.0	
	Completely Rehydrated		6.9			7.2			6.5	
30	Appearance	7.0	6.7	7.1	7.3	6.5	6.5	7.0	7.1	3.9
	Flavor Level	3.7	4.6	4.8	4.8	4.8	4.9	4.4	4.9	4.3
	Cooked Carrot Flavor	3.8	4.5	4.5	5.0	3.3	3.4	4.0	4.4	2.3
	Sweet	3.1	3.1	2.8	3.9	3.6	3.6	3.2	4.1	2.4
	Off-flavor	1.0	1.2	0.7	0.9	3.6	3.3	1.7	1.9	4.8
	Old, Stale	0.6	0.7	0.6	0.5	1.2	0.8	1.1	1.1	1.8
	Aftertaste	1.2	1.3	1.6	1.4	3.2	3.4	2.0	2.1	3.9
	Tough	1.2	1.0	1.4	0.8	0.9	1.3	1.8	1.8	2.2
	Mushy, Soggy	2.5	2.7	2.0	2.4	3.5	3.0	2.2	2.1	2.7
	Completely Rehydrated	6.9	6.8	6.6	6.9	6.9	6.9	6.5	6.6	6.0
60	Appearance	6.0	5.1	3.7	6.3	5.3	2.0	6.4	5.7	1.1
	Flavor Level	4.2	3.9	4.3	4.9	4.9	5.1	5.1	4.8	6.2
	Cooked Carrot Flavor	4.3	3.4	3.1	4.6	3.2	3.0	4.8	3.9	1.0
	Sweet	3.3	2.8	3.1	4.4	3.8	3.4	3.8	3.0	1.3
	Off-flavor	0.4	1.1	1.4	0.8	3.2	3.8	1.1	2.9	6.3
	Old, Stale	0.4	0.3	0.6	0.6	1.0	2.6	0.3	1.0	4.7
	Aftertaste	0.7	0.9	1.3	0.8	2.8	2.7	1.0	2.3	5.1
	Tough	0.6	0.4	0.4	0.3	0.3	1.0	0.6	1.2	2.4
	Mushy, Soggy	3.6	2.0	2.0	4.0	4.3	3.3	2.4	3.1	1.3
	Completely Rehydrated	6.8	6.3	6.0	6.9	6.8	6.1	7.0	6.6	5.3
90	Appearance	6.6	3.7	2.4	6.4	5.6	1.6	6.3	5.4	1.4
	Flavor Level	4.3	3.7	3.9	5.1	5.0	4.9	5.8	5.1	4.5
	Cooked Carrot Flavor	4.3	3.0	3.3	5.0	4.1	2.4	5.5	4.3	2.1
	Sweet	2.6	2.1	2.2	4.2	3.5	2.7	4.2	3.1	1.8
	Off-flavor	0.8	2.8	2.3	0.7	1.5	5.0	0.5	1.9	5.8
	Old, Stale	0.3	1.7	1.1	0.5	0.7	3.4	0.4	0.9	4.2
	Aftertaste	1.1	2.4	1.8	1.4	1.6	3.7	0.6	2.4	3.7
	Tough	0.4	0.2	0.6	0.2	0.3	0.8	0.2	0.7	0.9
	Mushy, Soggy	3.5	4.4	3.0	3.4	4.0	4.1	3.3	3.1	3.9
	Completely Rehydrated	6.7	6.8	5.9	6.7	6.8	6.7	6.7	6.6	6.3

TABLE XXXIX

OBJECTIVE MEASUREMENTS OF COOKED SHRIMP
(Zero Storage Time)

Treatment / Parameter	12.5% Propylene Glycol 25% H_2O #23	5% Propylene Glycol 5% Steam #49	7.5% Propylene Glycol 2.5% Steam #55
Moisture content after compression (%	8.1	6.2	5.5
Moisture content after rehydration (%)	76.3	71.7	72.8
Density before compression	0.20	0.20	0.19
Density after compression	0.89	0.87	0.85
Rehydration time (minutes)	17.0	13.5	8.5
Color:			
Lightness (L)	79.6	78.7	79.5
Redness (a)	7.0	7.0	6.0
Yellowness (b)	15.4	16.0	15.1
Microbial Counts	< 100	< 100	<100

TABLE XXXX

OBJECTIVE EVALUATION OF STORED SHRIMP

Storage time, days	Sample / Storage Temperature / Observation	A -18C	A 28C	A 38C	B -18C	B 28C	B 38C	C -18C	C 28C	C 38C
30	Moisture %	5.3	5.5	5.3	3.4	3.3	3.6	1.7	1.3	1.6
	Density	0.74	0.73	0.73	0.78	0.74	0.72	-	-	-
	Expansion %	20.0	11.3	16.0	9.3	12.9	15.9	-	-	-
	Rehyd. Time, Min.	16.0	13.0	19.0	10.0	15.9	8.4	10.9	9.5	10.8
	Rehyd. Moisture %	73.9	72.0	74.4	71.1	74.7	67.0	75.5	71.8	74.7
	Microbial Count	<100	<100	350	750	200	200	150	100	<100
60	Moisture %	5.4	5.4	4.9	3.1	3.8	3.9	1.3	1.0	1.2
	Density	0.74	0.73	0.72	0.78	0.74	0.72	-	-	-
	Expansion %	20.0	11.3	17.9	9.3	12.9	15.8	-	-	-
	Rehyd. Time, Min.	11.5	8.4	7.4	12.2	7.5	12.0	8.5	8.6	9.0
	Rehyd. Moisture, %	68.5	68.6	69.7	70.5	72.4	70.6	70.8	70.9	70.7
	Microbial Count	<100	<100	<100	<100	<100	<100	<100	<100	<100
90	Moisture %	5.9	5.6	5.9	4.0	4.4	4.0	1.4	1.5	1.6
	Density	0.74	0.73	0.72	0.78	0.74	0.72	-	-	-
	Expansion %	20.0	11.3	17.9	9.3	12.9	15.8	-	-	-
	Rehyd. Time, Min.	17.0	12.0	14.0	15.0	14.0	15.0	13.0	14.0	13.0
	Rehyd. Moisture %	67.5	69.8	70.9	72.9	72.4	73.5	70.9	74.6	78.8
	Microbial Count	<100	400	<100	500	<100	<100	<100	500	<100

Pre-Treatment

A - 5% propylene glycol, 5% steam
B - 7.5% propylene glycol, 2.5% steam
C - Control, no additives

TABLE XXXXI

SHRIMP

SUMMARY OF SKEWED HEDONIC SCALE RATINGS

Treatment	Temperature .C	Time of Storage, days			
		0	30	60	90
CONTROL	-18	-	3.3	3.0	3.1
	28	3.4	2.9	3.3	2.4
	38	-	3.0	3.3	2.2
5% Propylene Glycol 5% Steam	-18	-	4.0	4.0	3.0
	28	3.6	2.5	3.0	3.1
	38	-	2.5	3.1	2.4
7.5% Propylene Glycol 2.5% Steam	-18	-	2.9	4.0	2.7
	28	3.3	3.0	3.4	2.3
	38	-	2.6	3.0	2.1

TABLE XXXXII

SHRIMP

SUMMARY OF PROFILE RATINGS

Storage time, days	Sample Storage Temperature / Attributes	A -18C	A 28C	A 38C	B -18C	B 28C	B 38C	C -18C	C 28C	C 38C
0	Appearance		5.4			5.4			4.6	
	True Shrimp Flavor		3.5			3.9			3.5	
	Off-flavor (fishy, iodine)		3.1			2.8			2.5	
	Old, Stale		2.0			1.3			1.5	
	Aftertaste		2.4			2.6			2.1	
	Rubbery, Tough		4.9			4.0			4.1	
	Completely Rehydrated		5.0			5.3			5.3	
30	Appearance	5.3	4.3	5.0	5.1	5.9	4.0	4.9	4.9	3.8
	True Shrimp Flavor	3.4	3.4	3.8	4.0	4.6	3.8	3.8	4.4	2.9
	Off-flavor (fishy, iodine)	2.9	2.4	2.8	1.9	2.8	3.8	3.5	2.8	4.3
	Old, Stale	2.3	2.1	2.1	1.8	1.1	2.4	2.3	1.6	2.4
	Aftertaste	2.4	2.8	2.0	1.9	1.5	3.1	2.4	2.0	3.1
	Rubbery, Tough	5.3	4.3	4.9	3.6	3.3	5.3	3.5	3.5	4.3
	Completely Rehydrated	5.9	5.8	6.0	6.3	6.8	5.9	6.3	6.3	5.6
60	Appearance	5.3	4.8	3.9	5.9	5.3	4.1	5.4	4.6	4.4
	True Shrimp Flavor	3.3	2.8	2.5	3.3	2.8	2.9	3.7	2.7	2.9
	Off-flavor (fishy, iodine)	2.3	2.0	2.3	1.3	2.5	3.3	1.9	2.7	3.3
	Old, Stale	2.0	3.2	3.4	1.4	2.5	2.3	1.1	1.9	2.8
	Aftertaste	2.0	1.8	2.4	1.1	2.3	2.7	1.3	2.0	2.0
	Rubbery, Tough	3.7	3.6	4.0	3.0	4.5	3.4	3.4	4.0	3.5
	Completely Rehydrated	6.0	6.1	5.6	6.5	5.8	6.1	6.1	6.4	5.9
90	Appearance	6.0	4.1	3.7	5.2	5.6	3.6	5.0	4.3	2.9
	True Shrimp Flavor	3.7	2.3	2.7	3.5	3.1	2.4	2.8	2.3	2.0
	Off-flavor (fishy, iodine)	0.9	2.7	4.3	5.8	2.3	4.1	2.2	3.0	3.9
	Old, Stale	1.4	3.9	3.2	1.2	3.3	3.9	1.8	2.5	4.3
	Aftertaste	1.6	3.0	2.5	1.5	2.3	3.0	1.5	1.7	3.3
	Rubbery, Tough	3.4	4.6	4.7	2.0	4.1	3.6	3.5	3.7	3.4
	Completely Rehydrated	6.6	5.7	6.3	6.9	6.3	6.0	6.5	6.3	6.0

Pre-treatment

A Control

B 5% propylene glycol, 5% steam

C 7.5% propylene glycol, 2.5% steam

TABLE XXXXIII

OBJECTIVE EVALUATION OF DICED COOKED CHICKEN ZERO TIME STORAGE

Treatment / Parameter	X 10% Glycerol 4% Steam	Y 15% Glycerol 5% Steam
Moisture Content after Compression (%)	5.7	6.0
Moisture Content after Rehydration (%)	56.9	54.4
Density before Compression	0.3	0.4
Density after Compression	1.1	1.2
Rehydration Time (Minutes)	15	15
Microbial Count (Microorganisms/Gram)	$<$ 10,000	$<$ 10,000

TABLE XXXXIV

OBJECTIVE EVALUATION OF STORED CHICKEN

Storage time days	Sample storage Temperature / Observation	A -18C	A 28C	A 38C	B -18C	B 28C	B 38C	C -18C	C 28C	C 38C
30	Moisture %	6.0	5.5	5.1	6.8	6.4	7.0	1.51	1.31	1.35
	Density	0.9	0.8	0.9	0.9	0.8	1.0	-	-	-
	Expansion %	21.0	46.8	30.1	26.4	45.2	22.4	-	-	-
	Rehyd. Time, Min.	14.5	13.9	20.0	14.4	14.2	17.6	8.0	9.0	8.5
	Rehyd. Moisture, %	55.0	52.0	50.5	52.4	52.1	56.6	55.6	53.4	56.2
	Microbial Count	<100	100	<100	<1000	<100	<100	200	<100	100
60	Moisture %	4.9	4.4	4.7	5.9	6.4	6.0	1.7	1.0	1.1
	Density	0.95	0.76	0.86	0.93	0.79	0.94	-	-	-
	Expansion %	20.4	50.8	32.4	26.4	48.9	24.0	-	-	-
	Rehyd. Time, Min.	15.0	16.0	20.0	12.0	20.0	20.0	10.0	8.5	9.0
	Rehyd. Moisture %	51.9	54.1	54.3	57.7	48.8	49.9	60.5	55.3	57.7
	Microbial Count	<1000	<1000	2000	<1000	1800	>1000	>1000	<1000	<2000
90	Moisture %	4.3	5.2	4.4	6.2	6.2	6.5	1.3	1.1	1.0
	Density	0.95	0.76	0.86	0.93	0.79	0.94	-	-	-
	Expansion %	20.4	50.8	32.4	26.4	48.9	24.0	-	-	-
	Rehyd. Time, Min.	17.0	19.0	20.0	16.0	19.0	20.0	11.5	13.0	10.0
	Rehyd. Moisture %	49.6	46.6	49.5	47.1	48.0	46.3	50.3	56.1	41.3
	Microbial Count	7000	>6000	>6000	5000	>6000	>1000	1.5×10^4	>5000	>5000

Pre-Treatments

A 10% glycerol, 4% steam

B 15% glycerol, 5% steam

C = Control, no additives

TABLE XXXXV

COOKED CHICKEN

SUMMARY OF SKEWED HEDONIC SCALE RATINGS

Treatment	Temperature C	Time of Storage, Days			
		0	30	60	90
Control	-18	-	5.9	5.6	5.9
	28	5.8	5.1	4.5	4.1
	38	-	4.3	3.3	2.9
10% Glycerol 4% Steam	-18	-	5.0	4.9	5.9
	28	4.0	3.4	2.5	2.1
	38	-	2.8	1.9	2.1
15% Glycerol 5% Steam	-18	-	4.6	4.6	5.9
	28	3.4	2.1	1.4	1.9
	38	-	2.4	1.8	1.8

TABLE XXXXVI
DICED COOKED CHICKEN
SUMMARY OF PROFILE RATINGS

Storage time, days	Sample / Storage Temperature / Attributes	A -18C	A 28C	A 38C	B -18C	B 28C	B 38C	C -18C	C 28C	C 38C
0	Appearance, Shape, Broken, Color		6.6			5.4			5.0	
	Flavor Level		5.8			5.0			4.1	
	Salty		2.7			2.3			1.8	
	Off-flavor		0.6			1.4			1.9	
	Old, Stale		0.8			1.3			1.1	
	Rancid		0.3			0.8			0.4	
	Aftertaste		1.0			1.6			2.3	
	Rubbery, Tough		3.1			4.4			5.2	
	Completely Rehydrated		6.6			6.3			6.3	
	Overall Quality		5.6			3.6			2.8	
30	Appearance, Shape, Broken, Color	5.8	6.1	6.0	5.8	3.3	2.3	5.7	2.5	2.3
	Flavor Level	5.0	4.8	4.9	4.3	3.7	4.5	4.9	4.4	3.3
	Salty	2.6	2.4	2.6	1.4	1.7	1.8	2.1	1.3	1.4
	Off-flavor	0.6	1.3	0.9	1.0	2.1	3.1	1.1	5.0	4.0
	Old, Stale	0.8	1.0	1.0	1.6	2.6	3.6	1.0	5.0	3.6
	Rancid	0.5	0.4	0.4	0.4	0.1	0.4	0.4	2.8	1.1
	Aftertaste	0.8	0.6	1.0	0.9	1.9	2.0	1.3	4.3	3.0
	Rubbery, Tough	3.3	2.9	3.9	3.9	5.3	5.0	3.4	4.8	6.7
	Completely Rehydrated	5.9	5.8	5.4	5.6	4.4	5.4	5.6	3.8	4.0
	Overall Quality	5.0	5.1	4.9	4.5	2.9	2.0	4.1	1.5	1.7
	Sweet			0.6			0.4			0.4
60	Appearance, Shape, Broken, Color	6.0	6.4	5.8	6.2	3.7	2.3	6.0	2.4	2.1
	Flavor Level	5.9	5.3	4.0	5.7	4.0	3.2	5.5	2.8	3.0
	Salty	2.8	2.2	2.4	3.1	1.9	1.9	2.8	2.0	2.0
	Off-flavor	0.4	2.1	3.8	1.1	2.1	3.4	1.8	3.6	3.1
	Old, Stale	0.3	2.0	2.0	0.9	3.2	4.6	0.7	5.3	4.2
	Rancid	0.2	1.3	1.6	0.2	0.6	0.7	0.6	1.4	0.8
	Aftertaste	1.6	2.3	3.1	1.5	2.3	2.6	1.6	3.3	2.1
	Rubbery, Tough	2.3	2.2	3.4	2.4	5.1	5.8	2.5	5.1	6.4
	Completely Rehydrated	6.2	6.1	5.6	5.8	4.4	4.3	6.1	3.4	3.4
	Overall Quality	6.2	4.6	3.8	4.8	2.5	2.1	4.8	1.6	1.6

TABLE XXXXVI (Continued)

Storage time, days	Sample storage temperature / Attributes	A -18C	A 28C	A 38C	B -18C	B 28C	B 38C	C -18C	C 28C	C 38C
90	Appearance, Shape, Broken, Color	6.4	6.0	6.1	6.0	2.3	2.0	6.1	2.1	2.1
	Flavor Level	6.3	5.5	3.9	4.0	3.4	3.6	4.6	4.0	2.9
	Salty	2.5	2.1	1.3	1.5	1.4	1.0	1.9	1.4	0.9
	Off-flavor	0.4	2.1	2.9	1.0	3.4	3.4	0.6	4.0	3.9
	Old, Stale	0.4	2.5	2.9	0.6	3.5	4.3	0.3	5.0	4.9
	Rancid	0.4	0.8	0.9	0.3	1.0	1.8	0.1	0.9	1.1
	Aftertaste	0.9	2.3	2.3	0.9	2.4	2.1	1.0	2.9	2.8
	Rubbery, Tough	1.8	2.6	2.3	2.0	4.8	5.9	2.1	5.4	6.2
	Completely Rehydrated	6.6	6.5	6.1	6.6	5.0	4.9	6.5	4.4	4.6

Pre-Treatment

A = Control

B = 10% glycerol, 4% steam

C = 15% glycerol, 5% steam

TABLE XXXXVII

OBJECTIVE EVALUATION OF MEATBALLS

Treatment / Parameter	15% Glycerol 5% Steam	10% Glycerol 4% Steam
Moisture Content after Compression (%)	5.3	4.1
Moisture Content after Rehydration (%)	66.4	65.8
Density before Compression	0.3	0.3
Density after Compression	1.6	1.4
Rehydration Time (minutes)	6.0	6.2
Microbial Counts	1.5×10^6	1.5×10^6

TABLE XXXXVIII
OBJECTIVE EVALUATION OF STORED MEATBALLS

Storage time days	Sample storage Temperature / Observation	A -18C	A 28C	A 38C	B -18C	B 28C	B 38C	C -18C	C 28C	C 38C
30	Moisture %	5.2	6.3	5.9	4.2	4.0	4.4	0.7	1.0	0.9
	Density	1.6	1.6	1.6	1.4	1.5	1.2	-	-	-
	Expansion %	-	-	-	-	-7.1	14.2	-	-	-
	Rehyd. Time, Min.	18.0	15.0	17.5	12.0	16.0	18.0	10.0	12.8	14.0
	Rehyd. Moisture %	61.7	63.5	62.2	53.9	58.2	49.7	53.9	54.6	54.5
	Microbial Count	9×10^3	*	2.2×10^4	*	*	*	8×10^3		6.0×10^3
60	Moisture %	5.6	6.5	6.1	4.4	5.0	4.8	1.5	1.6	1.7
	Density	1.6	1.6	1.7	1.4	1.5	1.4	-	-	-
	Expansion %	-	-	-6.2	-	-7.1	-	-	-	-
	Rehyd. Time, Min.	16.0	18.0	20.0	20.0	20.0	20.0	13.0	13.0	13.0
	Rehyd. Moisture %	63.4	68.7	68.5	59.0	56.0	44.7	57.0	54.6	56.7
	Microbial Count	1.5×10^3	3.5×10^3	9.5×10^2	1.7×10^3	3.0×10^5	1.5×10^3	1.5×10^3	0.5×10^3	5.5×10^3
90	Moisture %	5.8	6.5	6.0	4.3	4.9	4.8	1.2	1.5	1.1
	Density	1.6	1.6	1.7	1.4	1.5	1.4	-	-	-
	Expansion %	-	-	-6.2	-	-7.1	-	-	-	-
	Rehyd. Time, Min.	14.5	17.0	20.0	16.0	19.0	20.0	12.0	15.0	13.0
	Rehyd. Moisture %	65.5	62.0	62.4	59.3	59.8	61.2	58.3	56.1	54.2
	Microbial Count	11.5×10^3	9×10^3	15.5×10^3	19.5×10^3	2×10^3	23×10^4	13×10^3	3.0×10^5	1.8×10^4

Pre-Treatments
A = 15% glycerol, 5% steam

B = 10% glycerol, 4% steam

C = control, no additives

* spread plates

TABLE IL

MEATBALLS

SUMMARY OF SKEWED HEDONIC SCALE RATINGS

Treatment	Temperature C	Time of Storage, Days 0	30	60	90
Control	-18	-	5.6	4.6	4.6
	28	4.7	5.3	3.4	4.6
	38	-	5.0	2.4	3.9
15% Glycerol 5% Steam	-18	-	4.6	4.8	3.5
	28	4.3	4.4	4.0	4.5
	38	-	4.5	3.9	1.5
10% Glycerol 4% Steam	-18	-	4.7	3.9	4.3
	28	4.2	3.3	2.8	3.0
	38	-	3.2	2.9	1.6

TABLE L
MEAT BALLS
SUMMARY OF PROFILE RATINGS

Storage time days	Sample Storage Temperature / Attributes	A -18C	A 28C	A 38C	B -18C	B 28C	B 38C	C -18C	C 28C	C 38C
0	Appearance (Shape, Color)		5.6			4.7			5.1	
	Flavor Level		4.8			4.9			5.0	
	Sweet		1.1			2.8			3.8	
	Aftertaste		1.7			1.9			1.8	
	Old, Stale		1.0			0.3			0.3	
	Mealy		2.8			2.4			1.9	
	Rubbery		1.2			3.6			3.1	
	Completely Rehydrated		5.6			5.7			5.8	
30	Appearance (Shape, Color)	5.3	5.2	5.5	5.1	4.6	4.7	4.4	4.4	4.0
	Flavor Level	5.3	5.4	5.5	5.0	5.1	4.6	4.8	5.1	4.6
	Sweet	1.9	1.8	2.2	3.1	3.7	2.9	4.0	3.4	4.0
	Aftertaste	1.2	1.6	1.7	1.7	1.9	1.4	1.8	2.6	3.0
	Old, Stale	0.9	0.9	1.9	1.1	1.9	1.1	1.0	3.0	2.8
	Mealy	2.6	2.7	2.6	2.3	2.8	3.1	2.1	3.0	3.6
	Rubbery	1.1	1.2	2.2	3.0	3.0	4.0	[illegible].7	4.4	2.8
	Completely Rehydrated	6.6	6.8	6.1	6.8	6.2	6.3	6.4	5.1	5.7
60	Appearance (Shape, Color)	5.0	5.6	5.1	4.4	4.6	3.4	4.8	3.8	3.9
	Flavor Level	4.9	5.2	4.0	5.2	5.2	4.8	5.0	4.3	4.4
	Sweet	1.9	1.0	1.3	2.8	2.9	2.8	3.0	2.3	3.1
	Aftertaste	1.3	2.6	2.4	1.6	2.0	1.9	1.8	2.3	2.0
	Old, Stale	0.8	2.0	3.0	1.3	2.6	1.5	1.5	2.5	3.1
	Mealy	2.0	3.0	2.9	2.4	3.2	3.5	2.6	4.1	3.9
	Rubbery	0.5	1.4	0.8	2.9	3.3	3.8	2.3	4.1	6.0
	Completely Rehydrated	6.4	6.3	6.1	6.1	5.9	4.9	5.4	4.0	4.7
90	Appearance (Shape, Color)	5.6	5.6	5.3	4.6	4.5	1.9	5.0	4.1	2.3
	Flavor Level	5.4	5.0	4.4	4.1	5.0	3.5	5.4	4.5	3.3
	Sweet	1.8	1.8	1.4	2.5	3.0	1.8	2.5	2.5	1.6
	Aftertaste	0.9	0.9	1.4	2.1	1.1	4.8	0.5	0.6	2.9
	Old, Stale	1.5	1.5	2.1	2.0	0.9	6.4	1.3	2.1	4.9
	Mealy	2.0	2.9	4.1	2.4	3.4	4.0	2.3	4.0	4.3
	Rubbery	1.4	1.4	1.4	3.0	3.5	4.8	2.1	3.9	3.8
	Completely Rehydrated	6.5	5.9	6.1	5.5	5.6	4.9	6.1	5.1	5.0
	Burnt						0.8			

A = Control
B = 10% glycerol, 4% steam
C = 15% glycerol, 5% steam

TABLE LI

OBJECTIVE EVALUATION OF CHICKEN AND RICE DINNER

Treatment / Parameter	7% Glycerol 5% Steam #201	5% Glycerol 5% Steam #202
Moisture Content after Compression	5.0	5.0
Density before Compression	0.28	0.28
Density after Compression	0.94	0.89
Rehydration Time (minutes)	20	20
Microbial Count Microorganisms / gram	< 10,000	< 10,000

TABLE LII

OBJECTIVE EVALUATION OF STORED CHICKEN AND RICE

Storage time days	Sample Storage Temperature / Observation	A			B			C		
		-18C	28C	38C	-18C	28C	38C	-18C	28C	38C
30	Moisture %	4.2	5.5	4.5	5.6	5.7	5.0	1.5	6.5	1.0
	Density	0.83	*	0.83	0.81	*	0.80	-	-	-
	Expansion %	12.0	-	9.0	12.0	-	11.5	-	-	-
	Rehyd. Time, Min.	20	20	20	20	20	20	20	20	20
	Microbial Count	<10000	<10000	4,000	2,000	25000	$>3 \times 10^6$	10000	1,000	4,000
60	Moisture %	4.2	5.2	4.3	5.5	5.8	4.9	1.5	4.8	0.9
	Density	0.84	-	0.84	0.82	-	0.82	-	-	-
	Expansion %	11.6	-	11.6	8.8	-	8.8	-	-	-
	Rehyd. Time, Min.	20	20	20	20	20	20	20	20	20
	Microbial Count	100	750	1,500	1,250	18200	9,100	2,000	7,500	1,300
90	Moisture %	3.8	5.1	4.5	5.3	5.6	5.1	1.5	5.0	1.1
	Density	0.85	-	0.84	0.81	-	0.80	-	-	-
	Expansion %	10.5	-	11.6	10.0	-	11.1	-	-	-
	Rehyd. Time, Min.	20	20	20	20	20	20	20	20	20
	Microbial Count	900	875	1,200	550	9,200	20000	5,500	10500	4,800

Pre-Treatment

A = 7% glycerol, 4% steam

B = 5% glycerol, 5% steam

C = control, no treatment

* crumbled

TABLE LIII

CHICKEN AND RICE

SUMMARY OF SKEWED HEDONIC SCALE RATINGS

Treatment	Temperature C	Time of Storage, Days			
		0	30	60	90
Control	-18	-	5.0	5.4	5.0
	28	6.0	5.3	6.3	5.4
	38	-	3.8	5.0	4.9
5% Glycerol 4% Steam	-18	-	3.4	5.3	6.0
	28	4.5	3.7	4.9	1.8
	38	-	-	1.5	1.4
7% Glycerol 5% Steam	-18	-	4.3	4.1	5.0
	28	4.5	4.1	3.9	3.3
	38	-	1.7	2.3	1.3

TABLE LIV
CHICKEN AND RICE
SUMMARY OF PROFILE RATINGS

Storage time, days	Sample Storage Temperature / Attributes	A -18C	A 28C	A 38C	B -18C	B 28C	B 38C	C -18C	C 28C	C 38C
0	Appearance		6.2			4.7			4.5	
	Toughness of Chicken		4.6			3.5			4.1	
	Completely Rehydrated Chicken		5.2			5.5			5.6	
	Flavor Level, Chicken		4.9			3.9			4.1	
	Distinct Rice Grains		6.8			4.4			4.2	
	Completely Rehydrated Rice		7.1			6.8			6.7	
	General Spice Level		5.3			4.2			4.5	
	Flavor Balance		5.4			4.3			4.8	
	Off-flavor		0.5			1.2			1.2	
	Old, Stale		0.3			0.9			0.6	
	Aftertaste		1.2			1.4			1.1	
30	Appearance	6.0	6.0	6.7	3.8	4.2		4.6	5.6	1.9
	Toughness of Chicken	4.1	3.8	4.3	3.3	5.0		3.6	3.7	4.1
	Completely Rehydrated Chicken	4.8	3.9	4.1	4.9	4.2		4.9	4.3	4.1
	Flavor Level, Chicken	4.3	4.1	3.9	3.7	4.3		4.9	4.0	2.8
	Distinct Rice Grains	6.6	5.9	6.7	3.8	4.7		4.7	5.6	3.4
	Completely Rehydrated Rice	6.4	6.2	6.7	6.9	6.4		6.4	6.3	5.7
	General Spice Level	4.1	5.2	3.8	4.3	4.2		4.8	4.1	3.3
	Flavor Balance	5.4	5.1	4.0	3.9	4.6		5.2	4.7	2.3
	Off-flavor	0.7	0.3	2.0	1.2	1.9		1.1	2.6	4.3
	Old, Stale	0.4	0.4	1.7	1.0	1.4		0.6	2.0	3.9
	Aftertaste	0.8	0.6	1.6	1.0	1.9		1.0	1.9	3.0
60	Appearance	6.0	6.1	6.0	5.6	3.7	1.5	3.8	3.7	2.1
	Toughness of Chicken	4.4	2.9	4.0	3.0	4.1	4.3	4.9	3.9	4.0
	Completely Rehydrated Chicken	4.3	5.6	5.1	5.7	5.1	4.1	3.5	5.4	4.4
	Flavor Level, Chicken	4.9	5.0	4.7	5.9	5.0	2.5	4.1	4.0	2.9
	Distinct Rice Grains	6.4	6.3	6.3	5.0	4.0	5.0	3.4	4.9	4.1
	Completely Rehydrated Rice	7.0	6.9	6.9	6.7	6.7	5.5	6.5	6.4	6.0
	General Spice Level	4.1	5.3	4.6	4.0	5.0	3.1	4.5	4.1	3.1
	Flavor Balance	4.6	5.6	4.1	4.9	4.7	1.5	4.6	3.6	2.4
	Off-flavor	0.5	0.4	1.1	0.4	1.1	5.8	0.6	3.0	4.[illegible]
	Old, Stale	0.6	0.3	1.3	0.6	1.1	4.9	0.8	2.0	4.0
	Aftertaste	0.8	0.5	0.6	0.6	1.0	3.0	0.6	0.4	2.9

TABLE LIV

(continued)

Storage time, days	Sample Storage Temperature / Attributes	A -18C	A 28C	A 38C	B -18C	B 28C	B 38C	C -18C	C 28C	C 38C
90	Appearance	6.3	5.1	6.2	5.6	1.7	1.0	4.4	2.8	1.1
	Toughness of Chicken	3.7	3.2	4.3	1.8	2.7	3.7	2.8	3.8	2.8
	Completely Rehydrated Chicken	4.6	4.9	4.2	6.1	5.0	5.3	4.8	5.0	4.1
	Flavor Level, Chicken	5.0	4.1	4.3	4.9	2.7	1.4	4.2	2.9	1.6
	Distinct Rice Grains	6.4	6.4	6.3	5.2	5.2	4.7	4.2	5.3	4.3
	Completely Rehydrated Rice	6.2	6.1	6.2	6.5	6.0	6.4	6.2	6.2	6.1
	General Spice Level	4.7	3.9	4.6	4.8	3.4	3.1	4.2	4.2	3.7
	Flavor Balance	4.9	4.3	4.8	5.1	1.9	1.1	4.7	3.3	1.0
	Off-flavor	0.1	0.9	0.9	0.1	5.1	5.2	0.3	1.8	5.9
	Old, Stale	0.4	1.3	1.0	0.3	4.7	4.1	0.6	2.0	4.8
	Aftertaste	0.9	0.8	1.0	0.7	1.7	3.0	0.7	1.0	3.3

Pre-treatment
A = Control

B = 5% glycerol, 5% steam

C = 7% glycerol, 5% steam

TABLE LV

OBJECTIVE EVALUATION OF CHILI CON CARNE

Parameter \ Treatment	5% Glycerol 4% Steam #101	2.5% Glycerol 4% Steam #102
Moisture after Compression (%)	4.0	4.0
Density before Compression	0.3	0.3
Density after Compression	1.26	1.26
Rehydration Time (minutes)	19	19
Microbial Counts Microorganisms/gram	< 10,000	< 10,000

TABLE LVI
OBJECTIVE EVALUATION OF STORED
CHILI CON CARNE

Storage time days	Sample Storage Temperature / Observation	A			B			C		
		-18C	28C	38C	-18C	28C	38C	-18C	28C	38C
30	Moisture %	6.1	4.7	5.3	3.7	4.4	4.3	0.75	0.75	0.75
	Density	0.84	0.83	0.83	1.00	1.00	0.89	-	-	-
	Expansion	33.3	34.1	34.1	20.6	20.6	29.4	-	-	-
	Rehyd. Time, Minutes	20	20	20	20	20	20	20	20	20
	Microbial Count	<10000	5000	2000	<10000	5000	5000	3000	7500	5000
60	Moisture %	6.0	4.5	5.5	4.0	4.1	3.4	0.75	0.75	0.75
	Density	0.84	0.84	0.82	0.97	0.95	0.95	-	-	-
	Expansion %	33.3	33.3	35.0	16.7	24.6	24.6	-	-	-
	Rehyd. Time, Minutes	20	20	20	20	20	20	20	20	20
	Microbial Count	2,100	800	900	13500	750	500	150	2750	1500
90	Moisture %	5.8	5.0	5.2	3.5	4.0	4.0	0.75	0.80	0.80
	Density	0.85	0.84	0.81	0.95	0.98	0.95	-	-	-
	Expansion %	32.5	33.3	35.7	24.6	22.2	24.6	-	-	-
	Rehyd. Time, Minutes	20	20	20	20	20	20	20	20	20
	Microbial Count	31000	22000	16000	21500	2900	1750	6200	5100	11500

Pre-Treatment
A 5% glycerol, 4% steam
B 2.5% glycerol, 4% steam
C control

TABLE LVII

CHILI CON CARNE

SUMMARY OF SKEWED HEDONIC SCALE RATINGS

Treatment	Temperature C	Time of Storage, Days			
		0	30	60	90
Control	-18		3.7	3.9	2.7
	28	4.3	2.4	4.2	2.1
	38	-	4.0	3.1	2.2
2.5% Glycerol 4% Steam	-18	-	4.0	4.7	4.8
	28	5.4	3.4	4.3	3.4
	38	-	1.9	1.4	1.4
5% Glycerol 4% Steam	-18	-	4.8	5.8	5.4
	28	3.9	2.4	4.6	3.7
	38	-	2.5	1.6	1.7

TABLE LVIII
CHILI CON CARNE
SUMMARY OF PROFILE RATINGS

Storage time days	Sample Storage Temperature / Attributes	A -18C	A 28C	A 38C	B -18C	B 28C	B 38C	C -18C	C 28C	C 38C
0	Appearance		5.3			5.4			4.7	
	Color		6.0			6.0			5.6	
	Chili Flavor Level (heat)		4.2			4.6			4.7	
	Old, Stale		0.8			0.5			0.7	
	Aftertaste		2.1			1.9			2.6	
	Hardness of Beans		5.1			2.1			3.3	
	Mushiness of Beans		1.7			5.2			3.4	
	Completely Rehydrated		5.6			7.3			7.1	
30	Appearance	4.7	4.4	5.0	4.6	3.9	3.1	6.1	5.3	4.0
	Color	5.0	4.3	5.3	5.6	4.5	3.8	5.8	5.7	3.8
	Chili Flavor Level (heat)	4.3	2.8	4.3	4.9	4.1	2.5	4.8	4.0	3.1
	Old, Stale	0.7	3.3	1.0	0.1	0.3	4.3	0.4	1.7	2.9
	Aftertaste	1.1	2.5	1.0	1.0	1.8	4.3	1.4	2.6	2.4
	Hardness of Beans	4.4	4.4	3.7	2.4	0.5	1.0	3.1	3.7	3.9
	Mushiness of Beans	1.1	1.6	1.4	3.7	5.8	5.4	3.3	1.6	2.5
	Completely Rehydrated	4.9	4.5	5.4	6.1	6.4	5.9	6.4	5.1	5.0
	Sweet			0.3		0.3	0.6		0.1	0.3
60	Appearance	4.3	4.1	4.8	4.8	4.8	2.1	5.3	5.6	2.2
	Color	4.1	3.9	5.0	5.4	5.1	1.9	5.7	5.8	2.1
	Chili Flavor Level(heat)	4.1	4.0	3.1	4.7	4.2	1.9	5.1	4.6	2.8
	Old, Stale	2.0	1.9	3.1	0.3	0.7	4.9	0.7	1.3	4.4
	Aftertaste	2.2	1.4	4.2	1.9	1.4	6.3	1.4	2.4	4.1
	Hardness of Beans	4.0	3.7	3.4	1.8	2.8	2.3	3.4	2.8	3.4
	Mushiness of Beans	2.0	2.6	2.4	4.6	4.7	4.4	2.3	2.8	2.7
	Completely Rehydrated	5.1	5.3	5.9	6.7	6.2	6.2	6.6	6.2	5.4
	Burnt						0.6			0.7
90	Appearance	2.7	2.9	2.4	4.9	4.4	1.3	5.7	5.6	1.7
	Color	3.6	3.8	3.7	4.7	4.6	2.2	5.2	5.0	1.9
	Chili Flavor Level(heat)	3.4	2.9	2.6	4.8	4.1	2.6	4.9	4.1	3.3
	Old, Stale	3.4	4.6	4.2	0.9	1.9	5.3	0.1	2.4	5.7
	Aftertaste	3.2	5.1	3.9	1.2	1.9	5.0	1.4	2.7	4.1
	Hardness of Beans	3.8	3.6	4.1	1.7	1.8	1.7	2.9	3.1	2.9
	Mushiness of Beans	1.7	2.0	1.1	4.2	4.2	4.9	2.7	3.0	3.3
	Completely Rehydrated	4.7	5.3	4.9	6.3	6.3	6.3	6.4	6.2	5.9

Pre-Treatments
A Control
B 2.5% glycerol, 4% steam
C 5% glycerol, 4% steam

TABLE LIX

OBJECTIVE EVALUATION OF BEEF STEW

0 STORAGE

Sample	Control No Treatment A	5% Glycerol 5% Steam B	10% Glycerol 4% Steam C
Moisture Content %	2.0	5.5	6.0
Density before Compression gram/cc	0.18	0.18	0.18
Compressed Density before Storage gram/cc	-	1.1	1.0
Separation Time	-	10	10
Rehydration Time (minutes)	20	20	20
Microbial Count Microorganisms/gram	250	550	850

TABLE LX
OBJECTIVE EVALUATION OF STORED
BEEF STEW

Storage time days	Sample Storage Temperature / Observation	A			B			C		
		-18C	28C	38C	-18C	28C	38C	-18C	28C	38C
30	Moisture %	2.1	1.8	1.7	5.8	4.9	5.1	6.1	6.0	6.1
	Density	-	-	-	1.0	0.95	0.91	0.99	0.91	0.97
	Expansion %	-	-	-	10.0	13.6	17.3	1.0	9.0	3.0
	Rehyd. Time, Min.	20	20	20	20	20	20	20	20	20
	Microbial Count	350	225	400	425	100	250	975	900	750
60	Moisture %	2.0	1.6	2.1	5.6	6.1	5.1	5.8	5.4	5.9
	Density	-	-	-	0.95	0.90	0.90	0.96	0.85	0.89
	Expansion %	-	-	-	13.6	18.2	18.2	4.0	15.0	11.0
	Rehyd. Time, Min.	20	20	20	20	20	20	20	20	20
	Microbial Count	425	150	550	300	400	375	600	1100	925
90	Moisture %	1.8	2.3	1.9	6.1	6.3	5.9	5.7	5.5	6.1
	Density	-	-	-	0.93	0.90	0.90	0.93	0.89	0.91
	Expansion %	-	-	-	15.5	19.1	19.1	7.0	11.0	9.0
	Rehyd. Time, Min.	20	20	20	20	20	20	20	20	20
	Microbial Count	300	<100	600	200	525	450	350	1250	1000

Pre-Treatment

A = Control, no treatment
B = 5% glycerol, 5% steam
C = 10% glycerol, 4% steam

TABLE LXI

BEEF STEW

SUMMARY OF SKEWED HEDONIC SCALE RATINGS

Treatment	Temperature C	Time of Storage, Days 0	30	60	90
Control	-18	-	5.1	5.4	5.3
	28	6.3	4.3	4.4	3.8
	38	-	4.5	4.4	4.3
5% Glycerol 5% Steam	-18	-	5.0	5.5	4.0
	28	5.1	4.7	4.9	2.7
	38	-	4.3	3.6	2.3
10% Glycerol 4% Steam	-18	-	4.9	5.6	5.3
	28	5.6	4.0	4.0	2.0
	38	-	4.2	4.1	2.5

TABLE LXII

BEEF STEW

SUMMARY OF PROFILE RATINGS

Storage time days	Sample Storage Temperature / Attributes	A -18C	A 28C	A 38C	B -18C	B 28C	B 38C	C -18C	C 28C	C 38C
0	Appearance		6.1			5.7			5.4	
	Beef Flavor Level		5.0			4.6			4.7	
	Spice Level		3.6			3.0			3.1	
	Old, Stale		0.6			0.7			0.6	
	Aftertaste		0.9			0.6			0.9	
	Tough Meat		3.0			4.9			4.3	
	Mealy Potatoes		1.9			1.4			0.9	
	Mushy Vegetables		2.0			2.3			2.0	
	Mouthfeel of Gravy		5.7			4.7			5.1	
30	Appearance	5.4	5.6	5.1	5.4	5.1	5.1	5.8	5.1	4.8
	Beef Flavor Level	4.9	4.3	4.1	4.3	4.7	4.4	4.4	4.4	4.8
	Spice Level	4.6	4.0	3.5	4.0	3.9	3.6	4.1	3.5	3.7
	Old, Stale	0.9	2.1	1.3	1.3	1.3	1.5	1.2	2.0	1.8
	Aftertaste	1.2	2.0	1.5	1.1	1.1	1.5	1.2	1.5	1.0
	Tough Meat	4.8	5.1	4.8	4.8	5.1	4.5	4.3	5.0	5.4
	Mealy Potatoes	2.7	3.0	2.5	2.0	2.4	1.5	2.1	1.5	2.7
	Mushy Vegetables	2.7	2.9	3.3	2.5	2.6	3.1	3.1	3.5	2.8
	Mouthfeel of Gravy	4.8	4.1	4.3	5.0	4.6	4.9	5.3	5.4	4.1
60	Appearance	5.6	5.3	4.9	6.0	5.4	4.5	5.6	5.1	5.0
	Beef Flavor Level	4.6	4.1	4.1	5.0	4.6	4.0	5.0	3.9	4.4
	Spice Level	3.8	3.5	4.0	4.1	4.0	3.4	4.1	3.4	3.5
	Old, Stale	1.3	1.5	2.0	0.8	1.3	3.3	0.8	2.8	2.6
	Aftertaste	1.0	1.9	1.9	0.6	0.9	2.1	0.6	2.0	1.6
	Tough Meat	3.3	4.5	3.6	3.0	4.6	5.0	2.9	4.6	5.5
	Mealy Potatoes	2.5	2.6	3.1	2.0	1.0	1.8	2.0	2.5	1.1
	Mushy Vegetables	2.3	2.4	2.9	2.1	2.4	2.6	2.6	2.9	3.4
	Mouthfeel of Gravy	4.8	4.4	4.6	5.3	4.8	4.9	5.5	4.3	4.5
90	Appearance	5.0	4.2	4.5	4.8	3.2	2.8	4.8	3.0	3.0
	Beef Flavor Level	4.3	3.0	3.3	4.2	3.0	3.0	5.2	2.7	3.0
	Spice Level	4.0	3.0	3.2	3.5	2.7	2.8	4.0	3.2	2.7
	Old, Stale	1.5	2.5	1.8	1.7	4.5	5.2	1.0	5.0	5.3
	Aftertaste	1.3	2.7	2.3	1.3	3.3	3.3	0.7	4.2	4.2
	Tough Meat	2.5	3.7	2.8	3.5	5.0	4.7	3.5	5.0	4.8
	Mealy Potatoes	2.2	2.5	2.0	1.8	3.3	2.2	1.5	2.5	2.3
	Mushy Vegetables	2.3	2.7	2.3	3.0	4.0	3.7	2.5	3.5	3.5
	Mouthfeel of Gravy	4.0	3.0	3.0	4.2	3.0	2.8	4.8	4.0	3.2

Pre-treatment

A Control; B 5% glycerol, 5% moisture; C 10% glycerol, 4% moisture

TABLE LXIII

OBJECTIVE EVALUATION OF DICED BEEF

0 STORAGE

Sample	Control No Treatment A	10% Glycerol 3% Steam B	5% Glycerol 4% Steam C
Moisture Content %	0.70	3.8	4.7
Density before Compression gram/cc	-	0.27	0.27
Compressed Density before Storage gram/cc	-	1.20	1.20
Separation Time	-	6.0	6.0
Rehydration Time (minutes)	20	20	20
Microbial Count Microorganisms/gram	< 100	< 100	< 100

TABLE LXIV
OBJECTIVE EVALUATION OF STORED BEEF

Storage time, days	Sample Storage Temperature / Observation	A			B			C		
		-18C	28C	38C	-18C	28C	38C	-18C	28C	38C
30	Moisture %	0.6	0.7	0.8	3.1	3.5	4.6	3.8	4.0	4.0
	Density	-	-	-	1.20	1.20	1.10	1.05	0.95	1.03
	Expansion %	-	-	-	0	0	8.3	12.5	21.0	14.2
	Rehyd. Time, Minutes	20	20	20	20	20	20	20	20	20
	Rehyd. Moisture %	53.5	54.0	56.0	60.0	59.0	57.0	61.0	58.5	59.0
	Microbial Count	<100	<100	<100	175	200	150	<100	<100	250
60	Moisture %	0.6	0.6	0.7	3.0	3.4	3.2	3.7	4.2	4.1
	Density	-	-	-	1.20	1.20	0.96	1.05	0.92	1.05
	Expansion %	-	-	-	0	0	20.0	12.5	23.0	12.5
	Rehyd. Time, Minutes	20	20	20	20	20	20	20	20	20
	Rehyd. Moisture %	56.6	52.3	51.0	57.2	55.0	50.0	60.2	60.5	56.1
	Microbial Count	<100	<100	<100	350	700	600	<100	<100	150
90	Moisture %	0.7	0.6	0.8	0.7	0.7	0.7	0.5	0.8	0.7
	Density	-	-	-	1.06	1.15	1.10	1.08	0.98	1.10
	Expansion %	-	-	-	11.7	4.1	8.3	10.0	18.3	8.3
	Rehyd. Time, Minutes	20	20	20	20	20	20	20	20	20
	Rehyd. Moisture %	59.7	55.3	50.4	58.9	54.3	57.1	61.0	57.6	56.4
	Microbial Count	<100	<100	150	<100	700	800	<100	<100	<100

Pre-treatment

A - control, no treatment

B 10% glycerol, 3% Steam

C - 5% glycerol, 4% steam

TABLE LXV

BEEF

SUMMARY OF SKEWED HEDONIC SCALE RATINGS

Treatment	Temperature C	Time of Storage, Days 0	30	60	90
Control	-18	-	5.6	3.9	4.8
	28	5.6	5.1	3.6	4.0
	38	-	3.9	2.9	3.9
5% Glycerol 5% Steam	-18	-	3.9	3.9	4.6
	28	4.5	4.3	3.7	2.9
	38	-	3.9	4.3	3.6
10% Glycerol 10% Steam	-18	-	4.0	4.3	3.6
	28	4.7	4.1	3.7	3.8
	38	-	3.7	2.4	2.1

TABLE LXVI
BEEF
SUMMARY OF PROFILE RATINGS

Pre-treatment: A - Control, B - 5% glycerol, 5% moisture; C 10% glycerol, 4% moisture

Storage time, days	Sample storage Temperature / Attributes	A -18C	A 28C	A 38C	B -18C	B 28C	B 38C	C -18C	C 28C	C 38C
	Appearance		6.0			5.1			5.2	
	Flavor Level		5.2			4.4			4.5	
	Salt		1.4			1.1			1.2	
	Off-flavor		0.2			0.3			0.6	
	Old, Stale		0.5			0.9			1.0	
0	Rancid		0.2			0.3			0.3	
	Aftertaste		0.8			1.0			0.9	
	Rubbery, Tough		3.2			4.1			4.0	
	Completely Rehydrated		6.6			6.1			5.8	
	Overall Quality		5.4			4.5			4.5	
	Appearance	5.6	5.6	5.6	4.1	4.6	5.3	4.9	5.0	4.7
	Flavor Level	4.1	5.1	3.5	3.6	4.4	4.0	4.4	4.3	3.9
	Salt	1.0	0.9	1.1	0.4	0.6	0.9	1.4	1.3	1.1
	Off-flavor	0.1	0.3	1.1	1.0	1.1	0.3	0.4	0.8	1.9
	Old, Stale	0.3	0.6	1.5	1.0	1.3	1.4	1.0	1.5	1.4
30	Rancid	0.1	0.1	0.3	0	0.3	0.1	0.1	0.3	0
	Aftertaste	1.1	0.9	1.5	1.9	1.9	1.5	1.0	1.6	2.0
	Rubbery, Tough	3.0	3.1	4.4	3.4	4.3	4.8	4.4	4.8	4.7
	Completely Rehydrated	6.0	6.4	5.6	5.9	6.0	5.9	6.1	5.8	5.9
	Overall Quality	5.1	5.1	3.8	4.0	4.3	4.0	4.0	3.5	3.7
	Appearance	5.0	5.3	4.7	4.0	4.4	4.9	5.1	5.0	4.0
	Flavor Level	4.0	3.4	3.7	4.1	4.0	4.4	4.3	3.9	2.9
	Salt	1.1	1.0	1.1	0.7	1.1	0.9	1.0	1.4	1.6
	Off-flavor	0.3	1.6	1.1	0.9	1.1	0.3	1.1	0.7	2.9
	Old, Stale	1.1	2.9	3.0	1.4	1.9	1.7	1.3	2.0	3.0
60	Rancid	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	1.4
	Aftertaste	0.7	1.3	1.0	0.7	0.9	0.9	1.1	0.7	1.9
	Rubbery, Tough	4.0	4.6	5.0	3.0	3.9	2.9	3.0	4.9	5.1
	Completely Rehydrated	5.4	5.4	5.6	5.6	5.9	5.6	5.6	5.6	4.4
	Overall Quality	4.0	3.3	3.4	4.3	3.6	4.6	4.4	3.6	2.6
	Appearance	4.9	5.3	5.8	4.5	4.3	3.9	3.8	4.9	2.9
	Flavor Level	4.9	4.4	4.3	4.4	3.9	4.3	3.8	4.3	3.1
	Salt	0.9	1.0	1.3	1.0	0.6	1.0	1.1	1.1	1.0
	Off-flavor	0.6	1.8	1.0	0.3	2.0	1.5	2.4	1.5	4.3
	Old, Stale	1.1	2.3	2.0	0.5	2.9	1.6	2.1	2.8	5.1
90	Rancid	0.3	0.5	0.4	0.1	0.1	0.1	0.1	0.4	0.9
	Aftertaste	1.4	2.1	1.6	1.1	2.1	2.3	1.6	1.9	3.4
	Rubbery, Tough	3.3	2.6	3.8	2.9	4.0	3.9	4.0	5.9	5.3
	Completely Rehydrated	6.5	6.1	6.4	6.9	5.9	5.8	5.6	5.6	5.5
	Overall Quality	5.0	3.9	4.6	4.9	3.3	3.6	3.9	3.6	2.3